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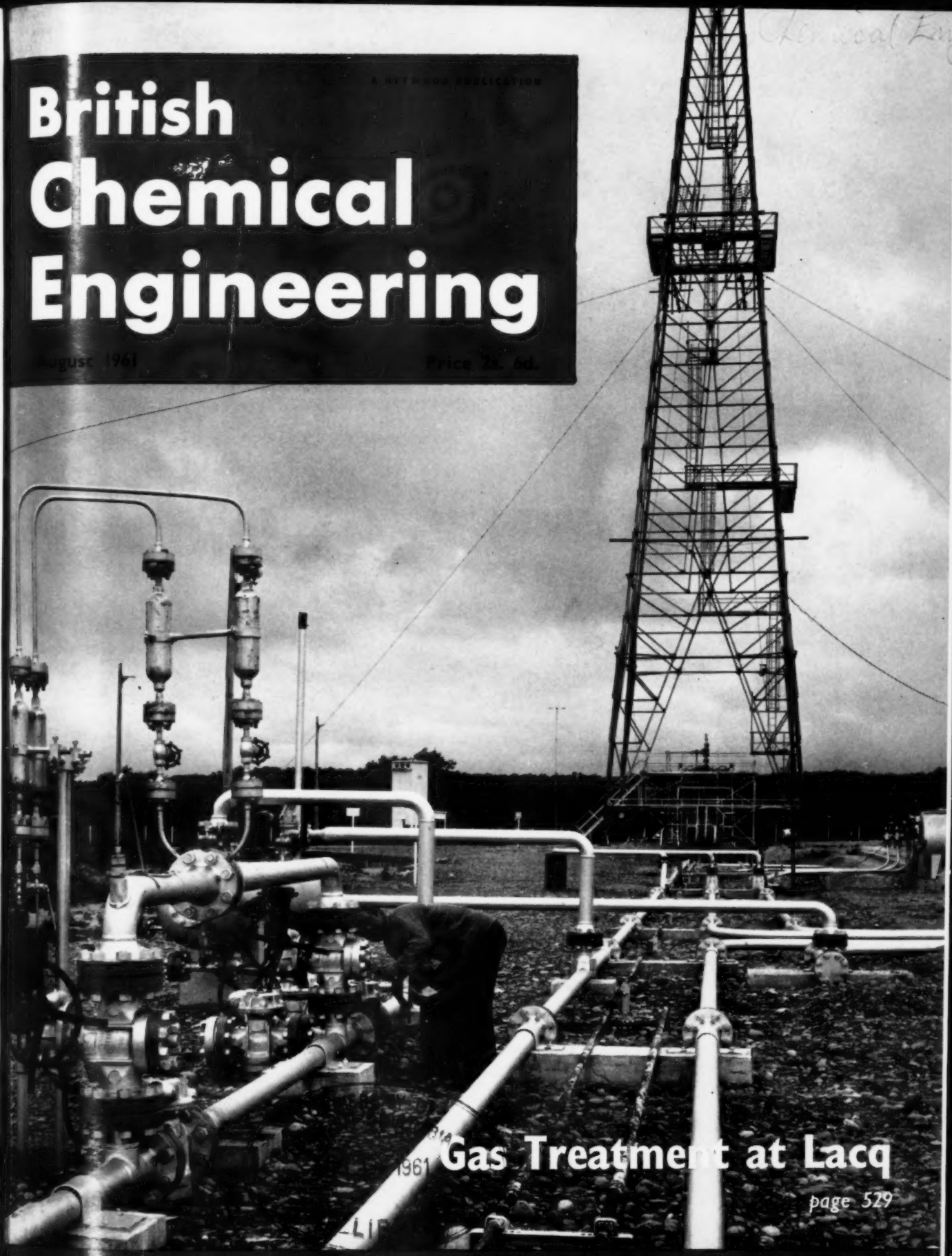

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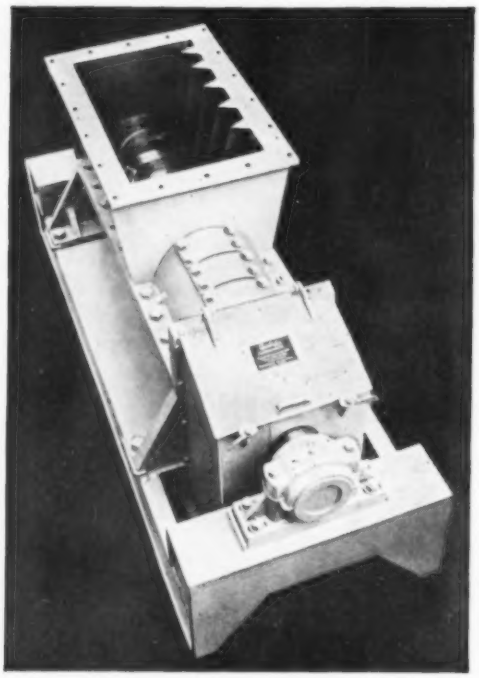
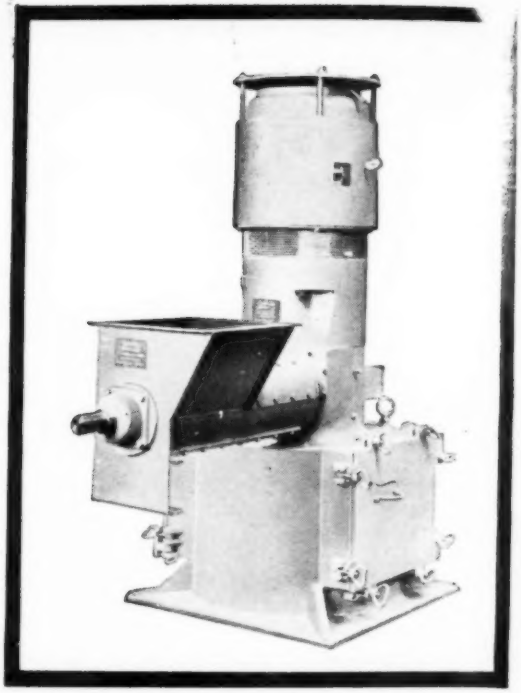
Scott-Rietz

PREBREAKERS AND DISINTEGRATORS FOR SIZE REDUCTION



PREBREAKERS are heavy duty machines utilizing low torque and low speeds and are designed for heavy crushing, skin shredding, hogging, and pre-treatment of larger particles before disintegration. The material fed into the hopper is crushed by rotating hammers in conjunction with anvils fixed to the base of the trough. Advantages are eveness of product size giving maximum charge to cooker, and minimum process time, low power consumption, slow operating speed, high throughputs, minimum maintenance costs.



DISINTEGRATORS are heavy duty, high speed machines which produce uniform particle size from materials in the small or medium range. The input can be fine to coarse, wet, moist or dry. An integral prebreaker can be fitted as a feeder to give preliminary size reduction. A special feature is that maintenance is particularly easy and screens can be replaced very quickly when worn, or it is desired to change the gauge. The exclusive Scott-Rietz differential discharge enables resistant or tramp materials to be automatically separated from the product.

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Scott-Rietz machines are manufactured in Great Britain under licence by George Scott & Son (London) Ltd.—one of the Balfour Group with its comprehensive Research and Development Centre.

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DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Dounreay's Gas Entrainment Problems Solved

A SERIOUS problem brought to light in the first physics experiments on the fast breeder reactor at Dounreay was the entrainment of bubbles of nitrogen in the liquid sodium/potassium coolant, revealed by small changes in reactivity. Under power conditions, gas entrainment would impair the heat transfer properties of the coolant, leading to local hot spots which in turn could bring about melting of the fuel. Preliminary tests showed that one source of trouble was in the liquid metal expansion tanks above the primary circuits; a drop in the liquid level allowed the inerting gas to pass down a pipe which was normally filled with liquid metal. Other sources of trouble were suspected and so, during the shut-down last year for change of core, the opportunity was taken to install trouble-shooting instrumentation and viewing devices to locate the trouble spots.

After extensive experiments, three causes of gas entrainment were established:

(i) the emptying of expansion tanks already referred to;

(ii) in the vertical tubes which form part of the control rod mechanisms, the pressure drop occuring at certain coolant flow rates caused nitrogen to be drawn down the tubes into the main circuits;

(iii) a similar effect occured in the instrument thermocouple tubes which lead down into the core.

The tank-emptying effect was found to be due to the blocking of certain small pipes. These are now being cleared. Relief holes and baffles are being provided in the thermocouple and control rod tubes to modify their hydraulic characteristics.

When this rectification work is complete, the possibility of raising the reactor power will be reviewed. So far the reactor has been working at low powers, up to 1.4 MW, to enable the physics of the system to be studied. The results have been encouraging. Chemical processing of the first DFR charge has been successfully carried out, proving the satisfactory operating characteristics of the fuel processing plant.

Iron and Steel Research

OUTSTANDING economies resulting from the use of oxygen in open-hearth furnaces are recorded in the annual report for 1960 of the British Iron and Steel Research Association, based on the results obtained by six companies. Using oxygen to enrich the combustion air for melting has cut fuel consumption by as much as 14 per cent, and reduced tap-to-tap times by up to 20 per cent in cold-charged furnaces. In hot metal furnaces, up to 12 per cent fuel saving has been recorded, with from 8 to 15 per cent reduction in tap-to-tap time. Oxygen lancing or jetting during the refining period has reduced fuel consumption by as much as 65 per cent as well as reducing refining time. In tilting furnaces the use of oxygen for refining has given an average fuel saving of 26 per cent and a tap-to-tap decrease of 24 per cent.

Experiments are now in progress with a pilot plant for the pretreatment of hot metal by spray refining, at the Redbourn works of Richard Thomas & Baldwins Ltd. In this process, a stream of molten blast-furnace metal is atomised by a suitable arrangement of oxygen jets, resulting in rapid oxidation and refining of the metal. Batches of hot metal up to 16 tons have been treated at rates of up to 2 tons/min., with oxygen flow rates ranging from 250 to 600 cu. ft./min. At low metal flow rates the metal can be adequately atomised and oxygen used very efficiently. Work is now in progress to develop an atomising device that will ensure adequate utilisation of oxygen at high metal flow rates to give any desired degree of refining.

Among other aspects of BISRA's work detailed in the report, the Iron Making Division are working on the problem of using the hot reducing gases from the high-temperature flame smelting reactor for pre-reduction of the raw ore in a a fluidised bed. Dirtiness of the gas is the major problem; several modifications to the design of grid or distributor have been made, but further development is still needed. As part of a design study for a production unit with an output of 200 tons of iron a day, an economic comparison between flame smelting and the blast furnace suggests that for conditions in the United Kingdom, flame smelting should produce cheaper iron but that the difference would not be very great.

Working on the measurement of the viscosities of synthetic slags, BISRA'S chemistry department have investigated melts containing CaF_2, and have confirmed that CaF_2 has a complex effect on the viscosity of $CaO\text{-}SiO_2\text{-}Al_2O_3$ slags: it has a much greater lowering effect on viscosity around 1250°C. than it has at 1500°C. Consequently, the effect of CaF_2 is not accounted for in the simple relationship which has been established between viscosity and composition in the system $CaO\text{-}MgO\text{-}SiO_2\text{-}Al_2O_3$.

Midland Industrialist

IN the development of the chemical industry in the Oldbury district there emerged a prominent leader, a man who was a rare combination of physicist, chemical engineer, and pure scientist, with the ability to adapt physical chemistry for the improvement of industrial processes. He was SIR RICHARD THRELFALL, F.R.S., the centenary of his birth falling on August 14. He had worked as a pure scientist under RAYLEIGH and THOMSON in the Cavendish Laboratory, and subsequently occupied the chair of physics until the time he entered industry. In 1898 he joined the board of Albright and Wilson, Limited, and from that point displayed as much ingenuity in the chemical process field as he had done in academic life. Adjoining the Oldbury heavy chemical industry established there by the Chance and Hunt company was also to be found ARTHUR ALBRIGHT'S phosphorous manufacturing plant, a process which had the benefits of Midland coal and canal transport as well as a ready supply of essential acids.

In the history of the growth of the more modern pro-

cessing methods for producing phosphorous and other products, the name of THRELFALL occurs again and again and his role was not confined to this field alone. He is equally prominent in the history of fused silica, glass and artificial diamonds and his was the genius which played such a decisive part in the development of techniques for the manufacture of ammonium persulphate, chlorates, carbon tetrachloride and silicic esters as well as phosphorous and its compounds.

THRELFALL had studied at Strasburg under FITTIG; thus it was natural that at Oldbury he should become more and more of an industrial chemist chemical engineer than physicist. There he fitted up a new research laboratory and developed in particular the electrolytic processes which the firm undertook in addition to its manufacture of phosphorous. Since chlorates were an obvious additional product to phosphorous for the match industry, and with the Albright concern being called upon to produce other chemicals during the first world war, a number of related processes developed. Thus chlorine from THRELFALL'S electrolytic process for making zinc from its fused chloride was used not only in phosphorus chlorides but for carbon tetrachloride manufacture. In patent specifications, in S.C.I. papers one of which won him a gold medal, and in the history of the Albright company, we read of THRELFALL'S electrolytic process for persulphates, his 8-cell plant being later sold to the Laporte interests for peroxide production, and his electrolytic chlorate process at Oldbury and Niagara. In his work on the electrolysis of fused chlorides he had made the largest mass of carbon ever made in Britain, a nine-ton block hollowed out as cell. In designing phosphorus furnaces, in his tunnel kiln for the continuous conversion at controlled temperatures of acid sodium phosphate to pyrophosphate, THRELFALL was as much a leader in development of these processes as he was in the production of incendiary missiles. His last important work was less dangerous, for while studying reactions of silicon tetrachloride he turned to the preparation of ethyl silicate and hence to long chain esters of complex silicic acid, esters which with alcohol and water he found to yield bonding-agents and colloids for "hardening" stone—all proving a spur to the development of silicones.

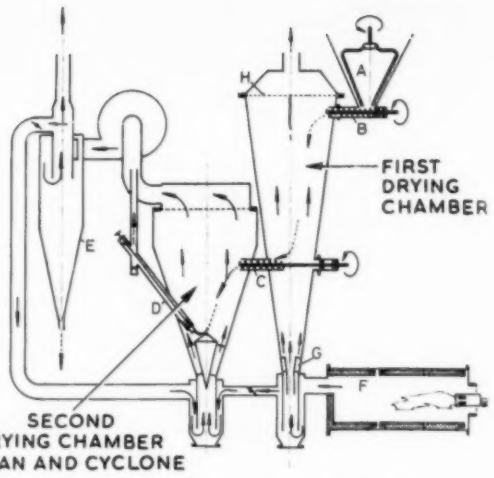
In the first world war RICHARD THRELFALL was prominent on the Scientific and Industrial Research advisory boards, on munitions boards, on chemical warfare committees and a chairman of the Fuel Research Board. He died on July 10, 1932, very soon after visiting Japan during a world power conference.

Drier for Sticky, Granular Materials

A SOLUTION to the problem of drying sticky materials which have also widely differing particle sizes—a task beyond most fluid bed driers—has been offered by a recent Norwegian design, based upon experimental work upon the drying of seaweed, carried out by the Norwegian Technical University.

In this drier the material to be dried is first cut up in a Gammer mill and fed to the apparatus where it is dried in a stream of hot gases passing up through conical shaped chambers, the gas velocity at the bottom being larger than the falling velocity of the largest particles, and at the top less than that of the smallest particles. Guiding vanes at the bottom of the chamber increase gas velocities near the wall so that the particles are carried upwards and fall down in a zone of lower gas velocities in the centre. Thus particles are whirled round and will break up lumps of feed material.

Raw material from the silo A (see diagram) is fed to the first chamber by the conveyor screw B. When 70-80% of the moisture is removed, another screw C takes the material to the second chamber. The finished product passes through the tube D, before being removed from the cyclone E. The hot flue gases from the combustion chamber F are drawn into the first chamber at G at about 40_m /sec, and leave through the wire gauze H at about 0.7_m/sec. Gas velocities in the second chamber are smaller, and most of the gas is recycled. The largest diameter at the top of the first chamber is 60 cm and at the second 70 cm. The capacity of the drier is 180 kgm raw material per hour. A good product was obtained when the inlet gas temperature to the first chamber was kept below 650°C, leaving both chambers at 70-100°C. The raw material had a moisture content of between 2.44 and 2.68 and the product from the first stage between 0.24 and 0.58 kgm water per kgm of bone dry material.



More than half of the moisture is removed in one minute, therefore automatic regulation was necessary. The conveyor screw B is driven by a 2-speed motor which is regulated by a thermostat in the exit gas from the first chamber. The screw C is started and stopped by the pressure differential over the first chamber, which is also a measure of the amount of material present.

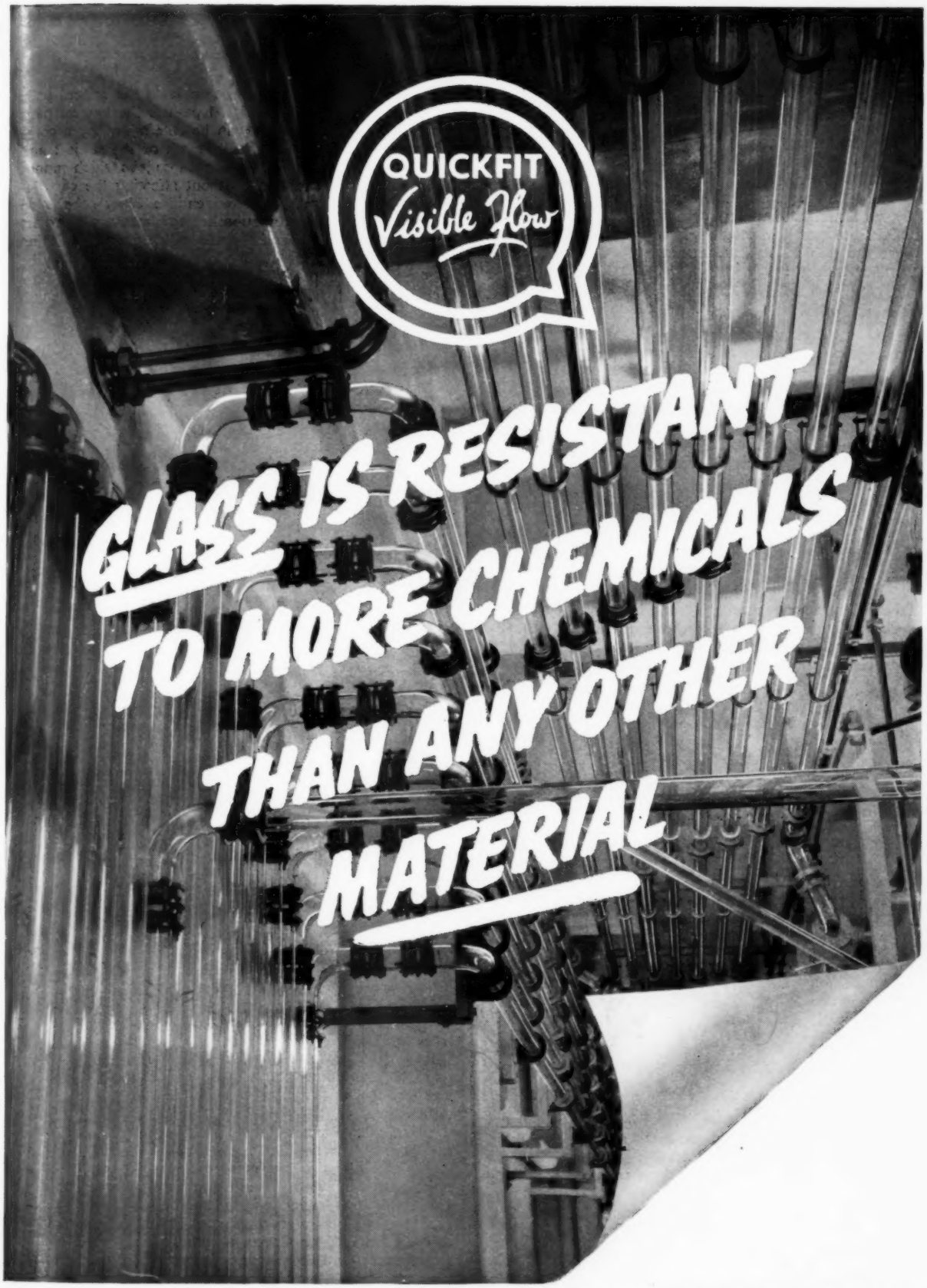
Although the prototype drier has a small capacity, its performance justifies commercial scale application for the drying of sticky granular materials.

(Described in *"Teknisk Ukeblad"* 1961, 23, 529.)

Freeze-drying of Foodstuffs

A SYMPOSIUM on the freeze-drying of foodstuffs will be held at the Borough Polytechnic, Department of Chemistry and Food Technology, on October 19th and 20th, 1961. The symposium will deal with the development of freeze-drying techniques, a survey of the commercial equipment at present available and a discussion of the potentialities of the technique in various branches of the food industry. Nutritional aspects will also be included. The panel of lecturers will include a number of persons who were concerned with the development of A.F.D. at Aberdeen and others who are at present installing and operating commercial equipment. Pilot plant and model freeze-drying equipment, samples of freeze-dried products and packaging materials will be on display.

Further details can be obtained from the Secretary, Borough Polytechnic, Borough Road, London, S.E.1.



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Critical Path Planning and Scheduling

Introduction

THIS is a new technique which resulted from an analysis of the traditional approaches to planning, made by Du Pont and Remington Rand in 1956. The technique graphically indicates the inter-relationships among the many organisations which contribute towards an overall project, and shows responsibilities of each group.

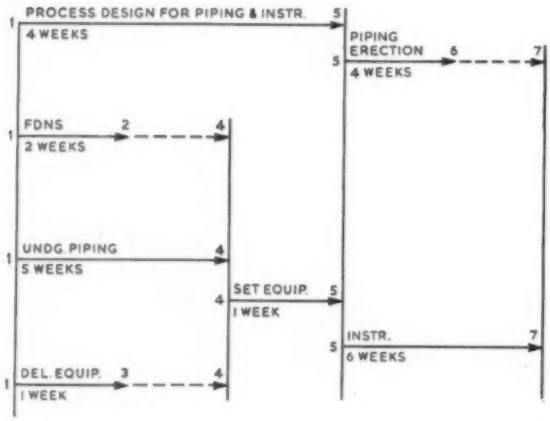
The following is a résumé of the technique as developed by the Lummus Company, which has successfully applied C.P.P.S. to complete projects. It is presented here to introduce the technique's fundamentals to those who are not familiar with it.

Elements of the technique

The application of C.P.P.S. to the design, engineering, procurement and construction aspects of chemical plant requires the separation of the functions of planning and scheduling. The overall project may first be divided into areas for ease of planning and a sequencing of events is decided upon. The planning done by areas will then be tied together to indicate inter-relationships within the overall project.

The work on each project is broken down into jobs, each of which is represented by an arrow which depicts the existence of a job and the direction of time flow for the job. A job can be defined as an item of work such as the design of foundations, the procurement of a compressor, the erection of a tower etc. It can be as large or as small as required for individual project needs. Each arrow is labelled to indicate the nature and duration of the job.

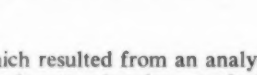
Scheduling must be completed when the project has been planned and the arrows inter-connected to show the sequence in which the various jobs will be performed.



When placing each arrow on the diagram, five questions must be answered:—

1. What immediately precedes this job?
2. What immediately follows this job?
3. What other jobs can be done cocurrently with this one?
4. What controls the start of this job?
5. What controls the completion of this job?

To interpret the completed network, each node—where the arrow or arrows start or meet—must be assigned a number, arbitrarily, such that the number on the tail (called the I node) is less than the number on the head (called the J node). These numbers only denote the forward direction of time flow:



When the network has been completed the critical path must be determined. The critical path is the longest path through the network and it can be determined by a computer, which figures the overall length of the project and shows the critical portions of it, i.e. those jobs which cannot be lengthened or shortened without affecting the completion date. The computer also identifies every other step in the project and its relationship to the overall project length. It gives the earliest possible starting and finishing times for each job. It tells by how much each job may be shifted without affecting any other job as well as the time each job may be moved without affecting the overall length of the project.

Dummy arrows are used to complete a logical statement of a plan, and are denoted by dotted line arrows which may or may not have time shown on them: 4— — —> 5

Job Scheduling

A time must be established at which the diagram will start. All jobs dependent upon this starting time must be related to it. Each arrow must be labelled and numbered. The origin number must be 1 or greater, never zero.

Considering the diagram it can be seen that the critical path is:—

1 to 4	5 weeks
4 to 5	1 week
5 to 7	6 weeks
	12 weeks to completion.

This network also shows that job 1 to 2 can move towards 4 by up to 3 weeks and job 1 to 3 could shift 4 weeks with no effect on the overall completion time.

Protective Coatings

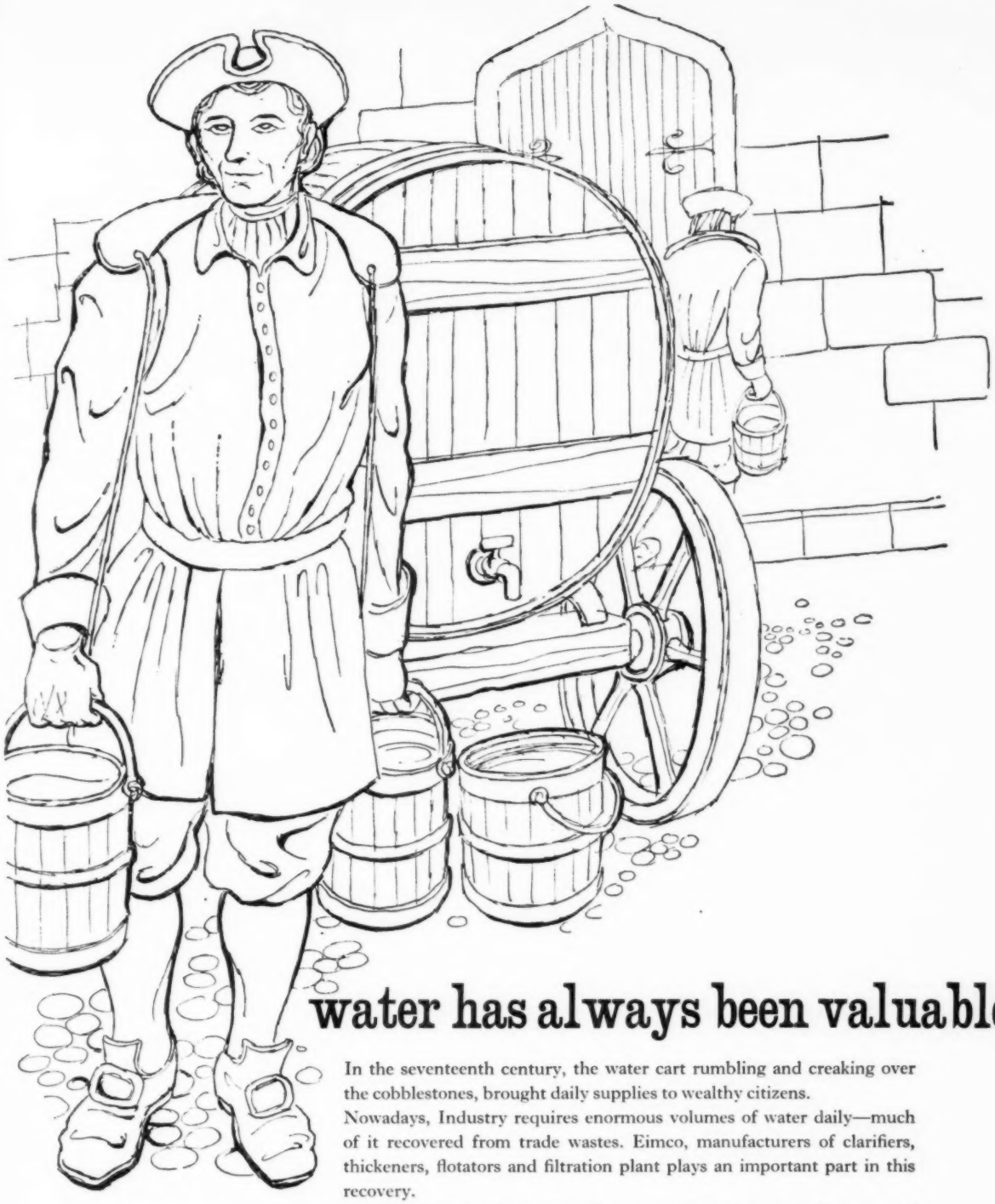
HOT dipped galvanised-coatings have given good results in studies of the protection of steel tanks in hot water systems, and of structural steel exposed to the atmosphere.* Pilot-scale tanks galvanised in zinc-aluminium baths have remained unpitted for well over a year both in aggressive natural water and in London water from which organic material encouraging the formation of a protective scale had been removed. Conventionally galvanised steel pitted rapidly in both of these tests.

For the protection of structural steel exposed to certain atmospheres, coatings in excess of 3 oz per sq ft are required. Such coatings may be applied by raising the galvanising temperature or by using certain alloy steels for the work, but there are practical objections to both methods. During the past year the British Non-Ferrous Metals Research Association have confirmed that such coatings can be produced on mild steel by prior surface treatment.

BNFMRA have also been investigating protective coatings for aluminium alloys. Sprayed coatings have given protection against corrosion under a wide range of conditions, and they provide valuable protection for high-strength alloys against stress-corrosion under stresses in the short transverse direction.

Research aimed at improving the durability of chromium plating have shown that as the thickness of chromium is increased to 0.00005 in or more, there is a progressive improvement in corrosion resistance. There are several types of bath from which thicker chromium can be plated free from cracks, and there is little difference in the corrosion resistance which they impart.

*Annual Report for 1960, British Non-Ferrous Metals Research Association, p. 22.



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Layering of Fluids

A SYMPOSIUM on Layering of Streams of Fluids of Different Densities was held at the Safety in Mines Research Establishment, Harpur Hill, Buxton on May 9th, 1961. Recent investigations into this problem, with particular reference to the formation of methane layers in mines, have been carried out at S.M.R.E. and Manchester University, and the results obtained so far were presented at this Symposium for the benefit of chemical engineers and other technologists having similar problems in this general field.

The phenomenon of heavy gases accumulating on floors and light gases accumulating on roofs was investigated from first principles by taking into account the buoyancy of fluid streams and neglecting the effects of viscosity and diffusivity. The motion and mixing of turbulent buoyant layers was found to depend on the slope of the tunnels or pipes, on whether the ventilation (in the tunnels) or fluid flow (in pipes) is downhill or uphill, on the wall roughness, and on the dimensionless expression

$$\frac{U_\delta}{\sqrt[3]{g\frac{\Delta\rho}{\rho}\frac{V}{D}}}$$

which has been called the Layering Number. In this expression, U_δ = Fluid velocity at the edge of the layer, in principle equal to the ventilation velocity.

$\Delta\rho$ = Density difference between fluids, before mixing,

V = Volumetric input rate of layer-forming fluid,

ρ = Density of layer-forming fluid,

D = Width of layer.

It is apparent that the ventilation velocity U_δ is more important than the rate of emission V, a fact which explains why very small rates of emission will nevertheless produce thin layers.

In horizontal tunnels, mixing by turbulence will occur if the Layering Number is greater than 2. Buoyancy has, however, a considerable influence at these conditions and, as a general rule, it is suggested that the Layering Number be not less than 5. This implies that for a methane input of 10 cu ft/min in a horizontal roadway 10 ft wide, the ventilation velocity would be 185 ft/min.

Slope has a marked effect on motion and mixing of methane layers. With uphill ventilation, relatively high ventilation velocities are required to mix the layers, and the greater the slope the greater the velocity required. The Layering Number should not be less than 5 at small slopes and not less than 8 at a gradient of 1 in 1.

With downhill ventilation a methane layer may move uphill, on account of its buoyancy, if the ventilation velocity is low. The Layering Number should be greater than 3 at small slopes and greater than 5 at a gradient of 1 in 1. Downhill ventilation has proved more effective than uphill ventilation.

Preliminary tests carried out in an 8 x 8 ft semi-circular arched section tunnel of slope 1 in 27 ($2\frac{1}{2}°$), indicate that baffles which obstruct the lower part of the tunnel may be used to disperse a layer, provided the velocity over the baffle is sufficiently high. Compressed-air ejectors have also proved effective in drawing a methane layer from the roof and discharging the mixed methane at the floor. Work is continuing on these and other possible means of dispersing methane layers in mines.

On the basis of present knowledge it would appear that the best approach to a methane roof layer problem will depend on the particular circumstances. The ventilating velocity can be increased, or methane emission reduced by methane drainage.

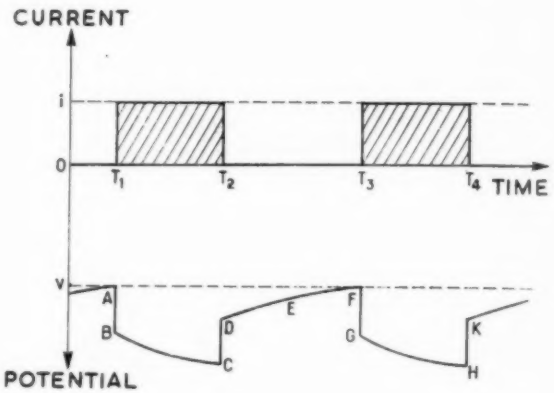
"*Methane Roof Layers*" by P. Bakke and S. J. Leach, S.M.R.E. Research Report No. 195, Nov. 1960, price 4s. 9d.

Relaxation of Potential: Basis of a New Technique in Cathodic Protection

THE standard procedure for cathodic protection is to apply a voltage to the structure requiring protection, sufficient to equal or slightly exceed the voltage attained by the structure in its environment. Voltage is applied and current supplied permanently and continuously. A disadvantage of such systems is that they make no allowance for the effect of changes in the environment, over periods of time, as in the case of materials exposed to the elements, buried or submerged.

A new process of cathodic protection overcomes this difficulty by fixing the *quantity* of electricity supplied to a metallic structure, during a certain time period, rather than in fixing the *current intensity*.

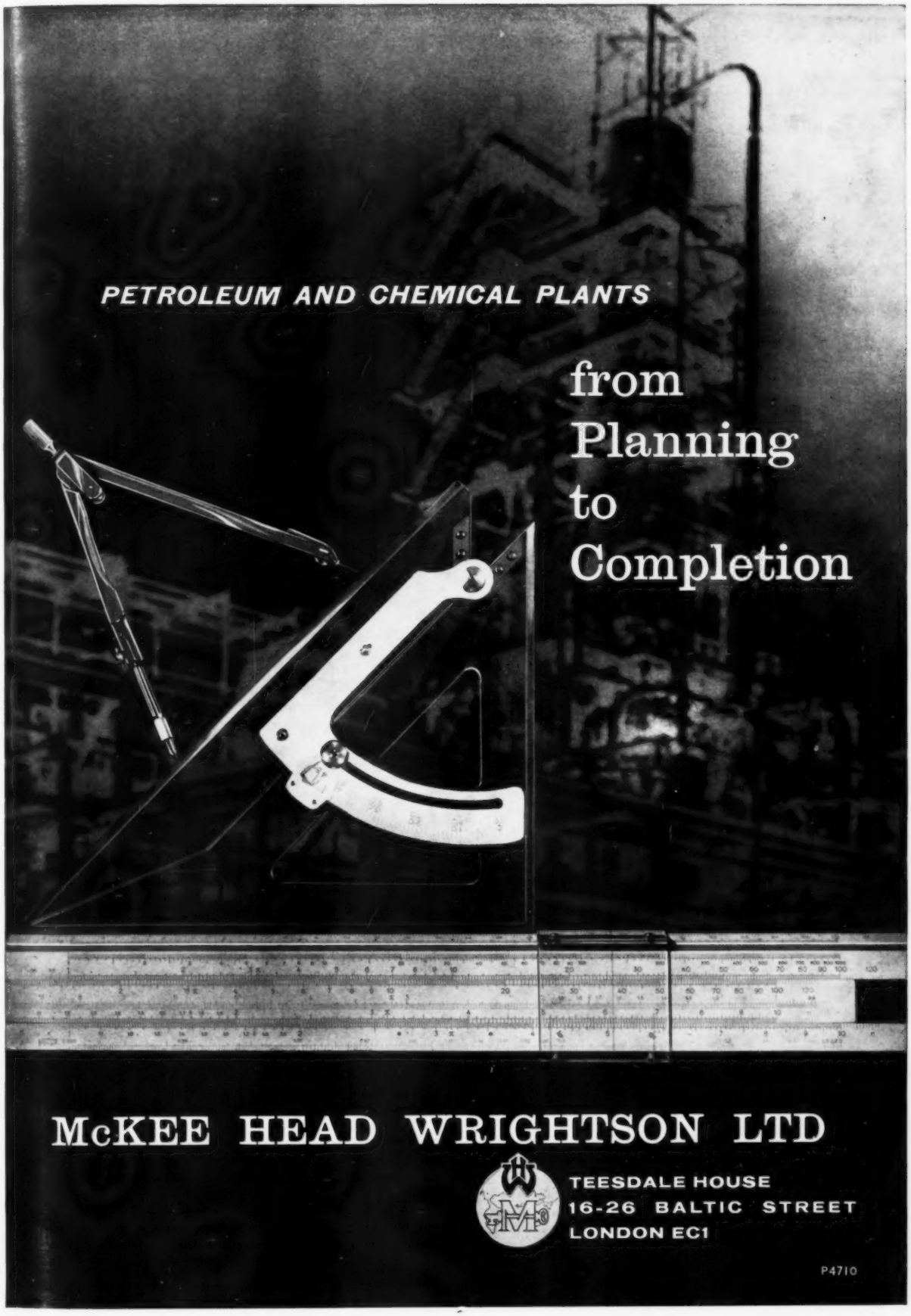
The introduction of time leads to the consideration of the quantity of electricity, supplied over a period, as a determining factor. This new experimental technique, which has given encouraging results, consists in supplying to the object a fixed quantity of electricity over a period.



POTENTIAL RELAXATION CYCLE

The supply is then stopped and its effect on the object's potential is noted. The magnitude of this potential determines when another quantity of electricity is supplied, e.g. when the potential of the object lies outside the immunity potential range. Potential is the main criterion of cathodic protection and it is essential that it be kept within the range of immunity. The quantity of electricity which must be supplied to an object to bring it within this range must be sufficient to compensate for the influence of the depolarisation factors. In this new method, the quantity of electricity supplied is self-adjusted, according to the magnitude of these factors, by the mere repetition of the cycle.

The figure shows how the method is used; the current is initially zero, then at instant T_1 current of intensity i is supplied. The potential of the object drops instantly by AB and varies gradually, according to the energy supplied. At T_2, current is stopped. The potential, having by then reached C, rises instantly by CD and evolves gradually, according to the influence of depolarisation factors. When the voltage attains a value V, pre-determined as the upper limit, more electricity is supplied at T_3 and this is the beginning of another cycle. The variables requiring pre-determination are: the potential V which triggers the electricity supply, the current intensity i and the period of its supply T_1T_2. The period T_1T_3, is not fixed in advance and may vary from one cycle to another, depending upon the activity of depolarisation factors.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Cathodic protection by this method is claimed to effect savings in electrical energy and anodic elecrodes especially where the consumption of electricity is high. The technique is proving successful with objects exposed to tidal waters but this application by no means exhausts the possibilities. The method has minimised overprotection and protection deficiencies in all circumstances.

From an article by Bernard Heufe in *Corrosion et Anticorrosion*, 1961 9 (3) 80-86.

Dual Vortex Flow in a Duct

AN interesting exhibit at the Aerodynamic Division of the National Physical Laboratory during the 1961 Open Days consisted of two air vortices flowing co-currently in the same duct without mixing.

Such vortices are generated by forcing air against sharp-edged plates having a convex leading-edge. In the particular exhibit at the N.P.L. an air draught was induced against a sharp-edged plate and the two vortices which were generated travelled co-currently along the duct. One vortex rotated clockwise, the other anti-clockwise, and there was no apparent mixing between them.

This type of flow permits greater heat transfer and drying rates in a duct, such as the cooling of articles on a conveyor belt. It has been successfully applied to rapidly cooling ice-cream, and there should be many other applications for this principle in industrial cooling, drying and heat transfer operations.

These plates may be set at suitable intervals along the duct, to generate persistent vortices which continue to flow slightly downwards behind the plates, and so pass very close to the articles to be cooled. By avoiding the generation of vortices which tend to break down, only one plate is required for many feet of efficient cooling.

The design of the plate is based on delta-wing aerodynamics and has been developed by workers in this field.

Mixing in a Vessel

Another exhibit worth the attention of chemical engineers concerned the mixing or stirring of fluids in a vessel. The mixer consisted of two cambered delta-shaped plates mounted at the ends of a rotating spar. Mixing of particles in a liquid appeared to be very effective at low speeds.

This method has been used to achieve temperature equilibrium within scientific apparatus much sooner than was possible with conventional methods and with less heat generated in the fluid.

Computer-Controlled Crude Oil Distillation Plant

AN overall increase in yield of the more valuable primary products and increased capacity have resulted from the installation of a computer-controlled unit at the Whiting, Indiana, oil refinery plant of the American Oil Company. Principal products of the unit, which was first demonstrated in October, 1960, are three napthas, two domestic fuel oils, three gas oils, and pitch-like residuum. Controlled by an IBM 704 computer, the output is 140,000 barrels a day.

Discussing the computer control system before a joint meeting of the American Institute of Chemical Engineers and the Chemical Institute of Canada, R. H. CROWTHER of Standard Oil Company (Indiana) said that computing on the IBM 704 must be infrequent to make it attractive. The minimum effective frequency had not yet been established. One round of computation per day was sufficient to provide accurate estimates of capacity limitations, yields and incentives to improve them. Operating safety was also improved by keeping the operators informed of loads at critical points in the system.

Plans for using smaller on-site computers have been developed for possible adoption when the relation between benefits and costs becomes clear. The experience gained throughout the development of computer control of crude-oil distillation is establishing principles for new, more profitable units designed to make full use of computer controls—as a replacement for some conventional controls and as a supplement to the rest.

Scale Down in Process Design

PROCESS design dealing with such typically Canadian problems as scaling-down of prototype plants, batch plants and multi-purpose plants will be one of the topics featured at the Chemical Engineering Conference scheduled for November 6-8, 1961, at the Royal York Hotel, Toronto, Ont. The Conference is sponsored by the Chemical Engineering Division of The Chemical Institute of Canada.

Special sessions will also be held on digital computers, chemical engineering aspects of nuclear engineering and kinetics of catalytic reactions. In addition there will be a session comprised of miscellaneous technical papers.

A highlight of the Conference will be the presentation of the R. S. Jane Memorial Lecture by a distinguished industrial engineering researcher.

A panel discussion on Graduate Research in Canadian Chemical Engineering Schools will be moderated by A. I. JOHNSON, McMaster University, Hamilton, Ont.

DIARY

Chemical Institute of Canada

August 3-5. 44th Canadian Chemical Conference and Exhibition, Queen Elizabeth Hotel, Montreal, Canada.

International Congress of Pure and Applied Chemistry

August 6-12. 18th Congress, Queen Elizabeth Hotel, Montreal, Canada.

U.N. Conference on New Sources of Energy

August 21-31. Rome. Information from — Executive Secretary, U.N. Conference on New Sources of Energy, United Nations, New York.

British Association for the Advancement of Science

August 30-September 6. St. Andrew's Hall, Norwich, Annual Meeting.

American Society of Mechanical Engineers and Others

August 28-September 1. International Heat Transfer Conference, Boulder, Colorado, U.S.A.

Registration information and advance programmes may be obtained from the A.S.M.E., Meetings Dept., 29 West 39th Street, New York 18, N.Y., U.S.A.

INTERNATIONAL HEAT TRANSFER CONFERENCE

PLANS for a five day International Heat Transfer Conference, August 28 to September 1, 1961, at Boulder, Colorado, have progressed so satisfactorily that the advance programme will be available early in April according to DR. A. C. MUELLER, Chairman of the Joint Committee on North American Participation. The conference, sponsored by four engineering societies, two American and two British, with participation by eight others, will be held on the campus of the University of Colorado. Papers will be presented by engineers from the United States, Canada, England, U.S.S.R., Japan, Poland, Australia, France, Switzerland, Scotland, Sweden, Germany and Yugoslavia.

DR. MUELLER also noted that over one hundred papers on recent original work and new applications in heat transfer theory and practice will be reviewed by reporters and discussion of the papers will be emphasised. All engineers and scientists are urged to attend and participate in the discussion. In addition, four lectures will review and synthesize recent developments in research and application. According to DR. S. P. KEZIOS, Secretary of the Committee on North American Participation, discussion at the Boulder Conference will be continued at a special meeting in London, England in 1962 under the auspices of the Institution of Mechanical Engineers.

Registration information and advance programmes may be obtained by writing to The American Society of Mechanical Engineers, Meetings Department, 29 West 39th Street, New York 18, New York. Advance registrants at the Boulder Conference will receive a bound copy of all papers before the meeting. Copies of the proceedings, including discussion at both the Boulder Conference and the London meeting, will be available in 1962.

A special feature of the conference will be talks by four visiting lecturers during the week. Lecturers and their topics are: PROFESSOR E. R. G. ECKERT of the University of Minnesota, "Heat Transfer Under Forced Convection Conditions"; PROFESSOR H. C. HOTTEL of Massachusetts Institute of Technology, "Gaseous Radiation"; PROFESSOR O. A. SAUNDERS of Imperial College, London, England, "Progress of Engineering Calculation of Heat Transfer"; PROFESSOR ERNEST SCHMIDT of The School for Technical Thermodynamics, Munich, Germany, "Heat Transfer Under Natural Convection Conditions."

Britain is represented by the Institution of Mechanical Engineers and the Institution of Chemical Engineers. Sponsors and co-hosts of the conference in the United States are The American Society of Mechanical Engineers and American Institute of Chemical Engineers. Also participating are the American Refrigerating and Air Conditioning Engineers, Chemical Institute of Canada, the Engineering Institute of Canada, the Institute of Aerospace Sciences, the Society of Automotive Engineers and the University of Colorado.

The first International Heat Transfer Conference was held in London, England, in 1951.

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P.O. Box No. 21
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In addition to filling these particular vacancies, applications are invited from young men aged 17/20 years, interested in science, with a view to training in the carbonisation and coal chemicals industry.

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Further information and application forms may be obtained from:-

J. A. Pateman, (D)
Appointments Department,
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London, E.C.1.

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New Zealand

Lecturer in Chemical Engineering

Applications are invited for the above-mentioned position in the Department of Chemical Engineering. Applicants should have an honours or higher degree in Chemical Engineering, or equivalent qualifications, such as an honours degree in Science and Associate Membership of the Institution of Chemical Engineers (by examination). An interest in Mass Transfer or Nuclear Chemical Engineering would be an advantage.

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Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, Marlborough House, Pall Mall, London, S.W.1.

Applications close, in New Zealand and London, on 31st August, 1961.

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DEPARTMENT OF CHEMICAL ENGINEERING

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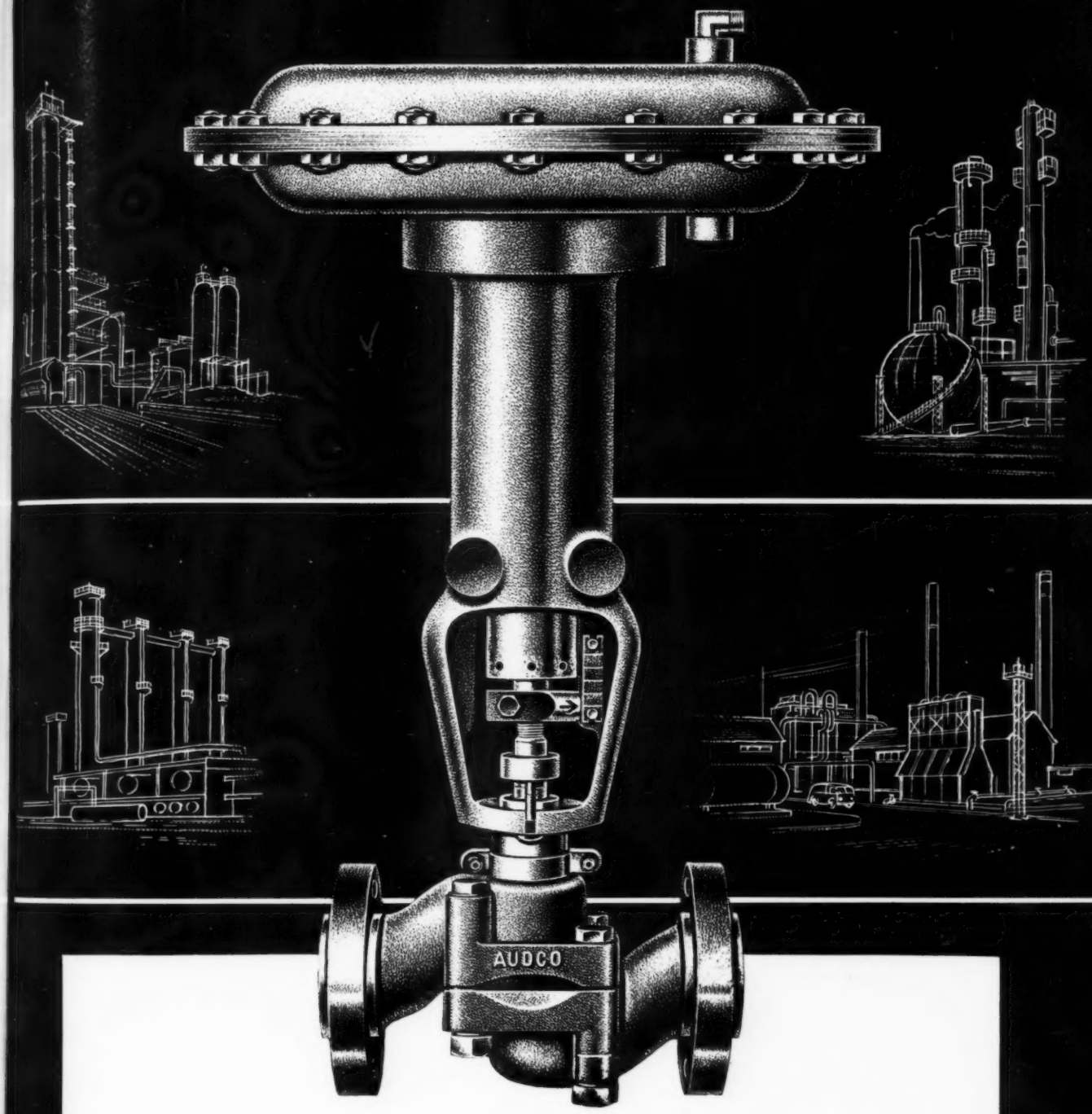

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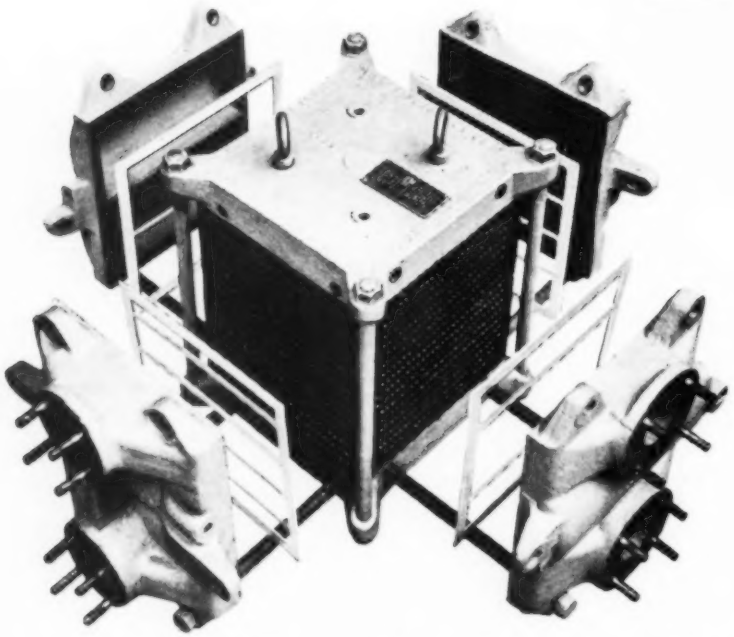

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Striking a Balance

RESEARCH can be classified into three groupings; pure, fundamental, and applied, the last-named being closely linked to development project work. The motive for the first is the search for knowledge for its own sake while that for the second is knowledge for practical purposes, although the specific nature of application is unknown when a research of this kind is initiated; the aim of applied research is the solving of particular technical problems in order, for example, to establish new processes.

One of the most interesting of present-day problems is where to strike a balance among these various phases of research and it is one which varies in complexity as one proceeds from the simplest unit engaged in research up to national or even international level.

The problem of balance is simpler at company level since the pure research element will be absent as many companies regard it as an unnecessary luxury. Nevertheless, the problem is still no easy one and such solutions as the adoption of competitors' ratios are over simple. In reality, this is a matter of trial and error and no hard and fast ruling is likely to be successful. Whatever the character of a company's business a dynamic approach is vital; at some point it may become apparent that the company is running short of new ideas, a situation which would call for an increase in fundamental work. On the other hand, there may be delays in applied projects caused by a stereotyped approach to applied work or through looking upon this field as inferior to the more basic field. In such a case the balance would favour an increase in the applied sector. One thing is certain, and that is that ready-made solutions cannot be evolved; what may be a solution today may well be out-of-date tomorrow.

While it is not our object here to put a case for fundamental research at company level, an indication of its importance would not be amiss. Properly conducted, it provides a reservoir of new ideas from which the company can choose for further developments in line with its interests; the specialist staff required for fundamental research constitutes a body offering the services of consultants, and capable of solving problems beyond the abilities of the company's operating staff; and it offers a scientific intelligence which keeps the company informed about all areas of science bearing upon its interests, thereby giving it the opportunity to apply rapidly new discoveries.

It is worth noting that fundamental research is comparatively inexpensive since its cost is often a tenth of that of an applied project and even less than this in comparison with pilot plant work. There is something to be said, therefore, for erring on the side of too much fundamental research.

While the question of striking the balance at company level may appear to affect the fortunes of the company alone, at national level there is much more at stake. In this intensely competitive era it is necessary that technology develops more rapidly than industry and that the natural sciences, which are the foundation stones of technical progress and the main source of the most profound technical ideas, should themselves outstrip technology. There then have to be considered major problems of the economy at present at the design stage, the long-term scientific investigations required to solve problems already recognized, and research aimed at disclosing the laws of nature in order to prepare the way for further scientific advances. The fact that something like half of the national effort in research is carried out by industry and a third by Government bodies suggests that much of research is carried out independently and that a variable balance exists among the various bodies carrying out research.

Possibly there already exists too much parallelism in some fields of research although this can be justified when fresh knowledge in certain fields is a matter of urgency, or where solutions to particular problems are vitally necessary. In such cases competition between teams may be an effective stimulus. But otherwise parallelism seems wasteful, a case in point being the amount of work carried out on various aspects of fluidization. This suggests the need for a much greater co-ordination of effort. At the same time one may question whether enough research is devoted to important fields such as the science of progress control; or to studies of processes and phenomena under conditions of extremely low or high temperatures and at exceptionally high pressures, for these are areas that are likely to yield a great deal that is fundamental and new.

Clearly, quite apart from how an actual balance is struck, there is the problem of what body is to perform the operation, or at least to offer some positive guidance to ensure that the combined research effort meets the interest of the nation, of industry, and of science itself. Primarily, but not exclusively, this is a matter of leadership and with all respect to the Minister of Science, in the absence of a supporting Ministry this is a task beyond him, and, indeed, beyond any other single human being.

Despite its magnitude this problem, along with a number of related tasks such as scientific education, will have to be faced realistically.

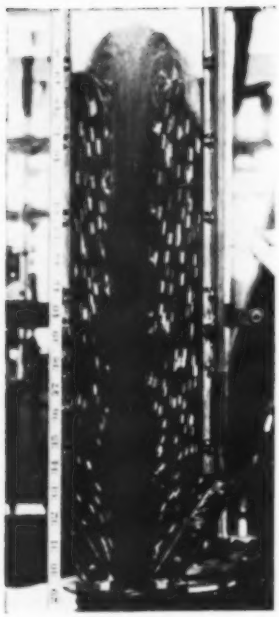

Fig. 1. Solids flow in the spouted bed.

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SOLIDS-AIR JETS

A review of previous studies of spouting is followed by an account of research in which the phenomenon is regarded as a jet mechanism. This approach casts light on some outstanding problems such as maximum spoutable bed depths, variance in spouting characteristics of various solids and solids spout diameters. There is a close similarity of spouting to channelling under fluidizing conditions in a bed. This point is illustrated by comparing the channelling pressure drop data of Max Leva with spouting pressure drop experiments described here. Finally, an equation similar to the Gishler-Mathur equation is derived for minimum velocity to spout solids beds.

by L. A. MADONNA,
R. F. LAMA and W. L. BRISSON

THE first paper to deal with the details of a jet of fluid moving through a bed of solids was published by GISHLER and MATHUR.[1] However, the name given to the phenomenon was not related to jets, but simply and aptly described as "spouting". Fig. 1 shows this system in operation in a 6-in. Pyrex tube. It should be noted that the solids are forced up the centre of the system by the moving air until it reaches the top of the bed, where it then drops back to the sides of the column. Fig. 2 gives the régimes of solids flow in the operation. It is quite obvious that the flow of solids is circulatory and symmetrical about the axis of flow of air through the column. The technique to indicate solids flow direction and velocity in the spouted bed is done by colouring most of the packing either black or blue and a few particles white. When the system is photographed in operation with an exposure time of one $\frac{1}{2}$ sec a trace is made of the particle movement within that time period. This is a convenient method to measure particle velocities in the column. Work along these lines will be presented in a future publication.

One of the major advantages claimed by the originators of this technique is that it handles particles that are in a size range far too difficult to fluidize. The sizes most easily handled are $\frac{1}{4}$ in. in diameter and over. This makes spouting highly acceptable in drying grains of various sizes and in economically sized lots. The technique was actually set up and tested for drying operations on wheat[2] and wood chips[3] at the National Research Council of Canada in Ottawa.

Also, GISHLER and MATHUR proposed an equation for predicting the minimum fluid velocity necessary to spout a given packing. This is given below as:

$$u_c = \left(\frac{D_p}{D_c}\right)\left(\frac{D_o}{D_c}\right)^{\frac{1}{3}}\sqrt{\frac{2g\,L\,(\rho_s - \rho_f)}{\rho_f}} \qquad \ldots.(1)$$

Since the latter equation did not predict minimum velocities for some systems, a modified equation has recently been developed[4] and is

$$u_c = \frac{D_p}{D_c}\left(\frac{D_o}{D_c}\right)^{n}\sqrt{\frac{2g\,L\,(\rho_s - \rho_f)}{\rho_f}} \qquad \ldots.(2)$$

$n = 0.23$ for 45° cone angle
$n = 0.13$ for 85° cone angle

It is obvious that n is a function of cone angle. This cone angle is the included angle of the entrance portion of the spouted column shown in Fig. 1.

At the very early stages of the investigation it was noted that beds of solids could not be spouted greater than certain given bed depths. These beds depths were called the "maximum spoutable bed depths" for that packing and apparatus geometry. The maximum bed depths were found to vary as to the type of packing used as follows[1]:

L_m for wheat: 30 inches
L_m for oats: 19 inches

The question is not yet resolved as to the correct relationship.

Apparatus

The apparatus of the present investigation is quite similar to that used by the previous researchers in this field. The set-up of the present authors is shown in Fig. 2.

Compressed air was used in all experiments, as it is the more simple fluid to regulate and the most important fluid in spouting bed studies.

Theoretical

Channelling and Spouting Factors

The fundamental theory behind the spouted bed operation must lie in the province of jet study, since the spouted bed is essentially an air jet issuing centrally through a packing. In fact, the entire mechanism bears a very close resemblance to the "channelling" discussed by MAX LEVA. In order to verify the above statement, a comparison between channelling and spouting pressure drop curves should reveal any similarities that do exist. Figs. 4 and 5 show the very distinct similarities between the two systems. It now seems that

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The work presented in this publication was performed at the University of Ottawa. We wish to thank the Canadian National Research Council for their support that made this endeavour possible.

channelling is an accidental by-passing of the fluidized bed where spouting is an intentional by-passing of a packed bed system.

To elucidate the similarities, define a "pressure deficiency factor" for a spouted bed as

$$X = \frac{\Delta P_M - \Delta P_s}{\Delta P_M} \quad \ldots . (3)$$

where ΔP_M = maximum pressure drop in the spouted bed;
ΔP_s = pressure drop at spouting.

As X⟶1, excellent spouting conditions are achieved.

Leva has prepared for fluidization channelling a graph of pressure deficiency factors for various solids versus particle diameters which is shown in Fig. 6. The diagram for spouting is shown in Fig. 7. It can be seen from the spouting diagram that the smaller the particle, the more difficult it is to spout. And in fluidization channelling the smaller the particles, the greater the tendencies to channel. In fluidization we are trying to terminate what we desire in the spouting mechanism. If Figs. 4 and 5 are studied it is seen that the only difference in the form of the pressure drop curves is after the maximum pressure drop is reached in each case. However, the values of these maximum pressure drops are not the same at all, for in fluidization this pressure drop is related to the force necessary to lift the bed of packing, while in spouting it is the maximum energy loss of the air jet before it completely penetrates the bed. Fig. 8 shows the position of the air jet in a bed of wheat operating in a split column at maximum pressure drop. The convenient use of a split column to reveal air and solids flow characteristics does not seem to alter the flow mechanisms appreciably.

Quantitative verification of the differences between maximum pressure drops shows that the fluidization pressure drop is always higher than that for spouting. This may be of some practical importance in the sizing of gas compressors for process use of the spouted technique.

Spouting and maximum pressure drops have been predicted in the equations of MADONNA and LAMA.[6] These were determined to be the following:

Maximum Pressure Drop

$$\frac{\Delta P_M}{L} = \frac{1120\, G\, \mu\, \lambda^2\, (1-\delta)^2}{D_p{}^2\, \rho_f\, g_c\, \delta^3} \quad \ldots . (4)$$

Spouting Pressure Drop

$$\frac{\Delta P_s}{L} = \frac{74\, G^{1.25}\, \mu^{0.75}}{g_c\, \rho_f} \left(\frac{\lambda}{D_p}\right)^{1.75} \frac{(1-\delta)^{1.75}}{\delta^3} \quad \ldots . (5)$$

Note that these equations are quite similar to the type suggested by LEVA for packed beds. This indicates that the major portion of the energy loss in this system is through the moving bed region or what is called the "annulus".

Maximum Spoutable Bed Depth

Another facet of spouting that has plagued investigators has been the fact that for a given orifice diameter and column diameter only a certain bed depth of a packing could be spouted.

GISHLER and MATHUR in their American patent[7] give a tentative formula to predict the maximum spoutable bed depth:

$$\frac{L_m{}^{0.7}}{D_c} = \varphi \frac{L_o{}^{0.6}}{D_c} \quad \ldots . (6)$$

As the above formula stands, it is not yet complete. At the maximum spoutable bed depth the jet of air and packing deviates from the centre position it normally holds and falls to the side of the column. This phenomenon appears to be very similar to ordinary air jet instability, but in this case the jet cannot easily retain its normal position. Even during normal spouting operations at lower bed depths and decidedly near the maximum spoutable bed depth the jet of air and solids sometimes oscillates around the axis of the column.

In order to show that jet instability was responsible for a limitation in bed depths in spouting, a number of beds were placed in series. This is shown in Fig. 10. Let a given bed depth be divided into an equal number of segments or stages. These stages now should contain spouting systems of higher stability than the original one-stage system. Experiments were performed on multi-stage spouted bed units and it was found that not only were the staged units more stable but the air requirement to spout the entire assembly was reduced compared to the accumulated stage bed depth requirement. The experimental data is shown in Fig. 11. An example will

Symbols Used

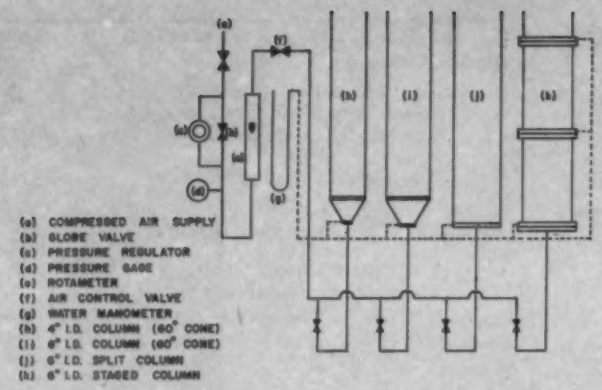
u_c = minimum velocity for spouting;
u_1 = velocity of air at section 1, ft/sec;
u_2 = velocity of air at section 2, ft/sec;
E_1 = internal energy at section 1, $\frac{\text{ft-lb}}{\text{lb}}$;
E_2 = internal energy at section 2, $\frac{\text{ft-lb}}{\text{lb}}$;
p_1 = static pressure at section 1, lb/ft²;
p_2 = static pressure at section 2, lb/ft²;
v_1 = specific volume at section 1, cu ft/lb;
v_2 = specific volume at section 2, cu ft/lb;
x_1 = distance from arbitrary datum to section 1, $\frac{\text{ft-lb}}{\text{lb}}$;
x_2 = distance from arbitrary datum to section 2, $\frac{\text{ft-lb}}{\text{lb}}$;
Q = heat, $\frac{\text{ft-lb}}{\text{lb}}$;
W = work, $\frac{\text{ft-lb}}{\text{lb}}$;
g_c = gravitational constant, ft/sec² or ft/hr²;
D_p = diameter of sphere of a volume equivalent to the particle volume, ft;
D_c = diameter of the column, ft;
D_o = diameter of the orifice, ft;
L = depth of packing, ft;
L_m = maximum spoutable bed depth, ft;
f = height fraction, $f = \frac{a}{L}$;
a = axial distance along solids-air jet, ft;
ΔP_M = maximum pressure drop in a spouted bed, lb/ft²;
ΔP_s = pressure drop at spouting, lb/ft²;
X = channelling factor or pressure deficiency factor;
G = mass velocity of air through bed, lb/ft²-hr;
C_s = correlating coefficient.

Greek Symbols

δ = void fraction of bed before spouting;
λ = particle shape factor;
μ = air viscosity, lb/ft-hr;
ρ = density, lb/ft³;
θ = included angle of cone at bottom of column, degrees;
α = coefficient of friction between solids and column material.

Subscripts

f = fluid;
s = solids;
c = column.


(a) COMPRESSED AIR SUPPLY
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(e) ROTAMETER
(f) AIR CONTROL VALVE
(g) WATER MANOMETER
(h) 4" I.D. COLUMN (60° CONE)
(i) 6" I.D. COLUMN (60° CONE)
(j) 6" I.D. SPLIT COLUMN
(k) 6" I.D. STAGED COLUMN

Fig. 2. Flow sheet of spouted bed apparatus.

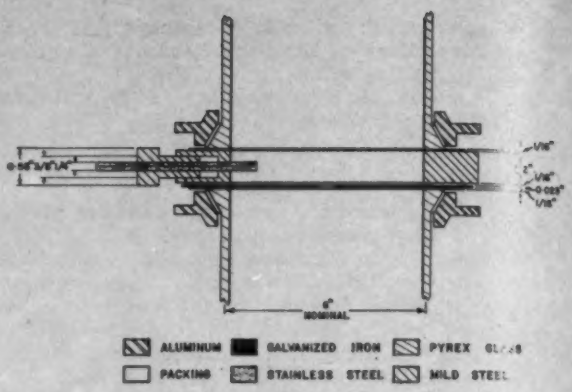

Fig. 3. Detail of lower column cone and flat bottom types.

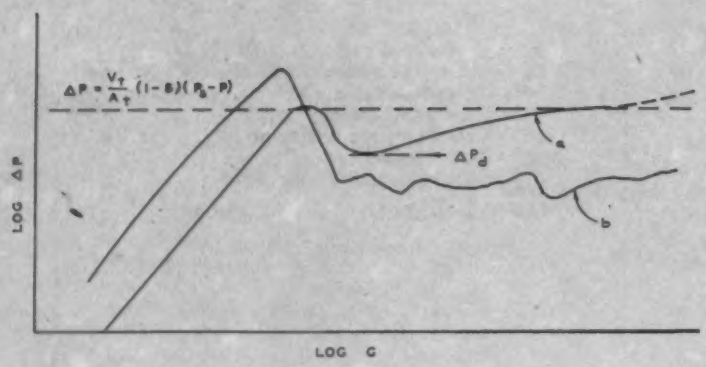

Fig. 4. Channelling pressure drop curve for a fluidized bed (MAX LEVA et al.).

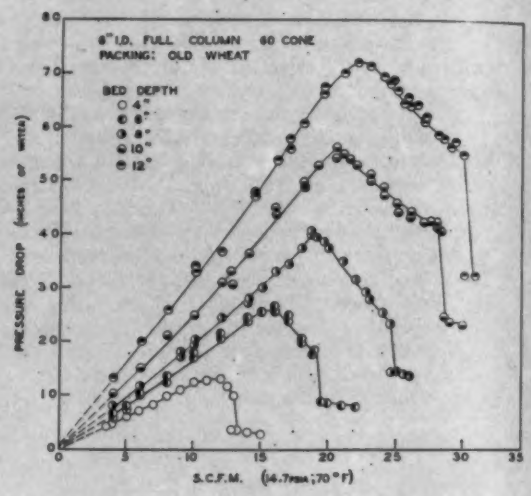

Fig. 5. Spouting pressure drop curves.

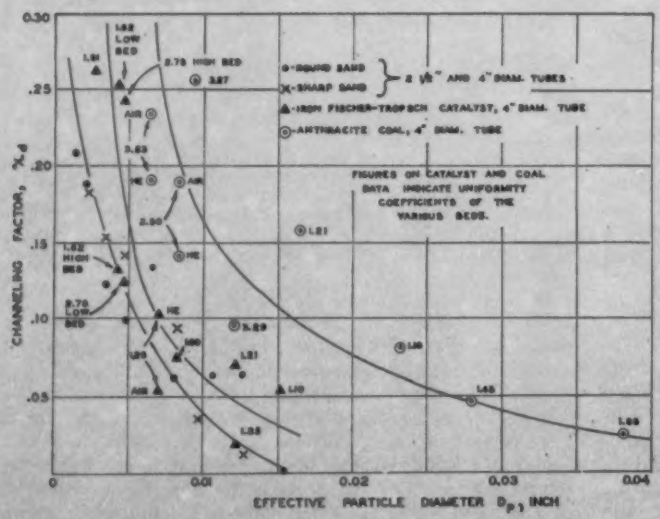
CHANNELING FACTOR, χ_d
EFFECTIVE PARTICLE DIAMETER D_{p1} INCH
FIGURES ON CATALYST AND COAL DATA INDICATE UNIFORMITY COEFFICIENTS OF THE VARIOUS BEDS.

Fig. 6. Pressure deficiency factors for channelling in a fluidized bed (MAX LEVA et al.).

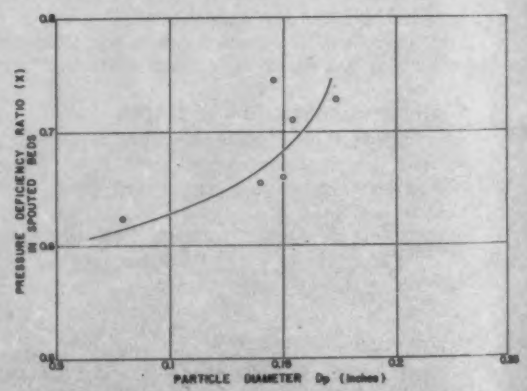

Fig. 7. Pressure deficiency factors for spouted beds.

indicate the phenomenon. For a two-stage system the following data are obtained from Fig. 11. If the bed depth in each stage is 6 in., then saving of air would be approximately 30 scfm − 23.6 scfm = 6.4 scfm.

Percentage of single-stage air requirement: $\frac{23.6}{30}(100) =$ 78.7 per cent.

Savings in air by using staging: 21.3 per cent.

Apparently by staging given total bed depths the jets of solids-air were stabilized so that large bed depths can be spouted with a reduced amount of air. The maximum number of stages tried in a 6-in.-diameter glass column to date has been four. The reforming of air jet between stages seems to be an important factor. However, the above experiments were not carried on past four stages, so that the proof presented is most qualitative and incomplete.

Commercially staged spouted beds have promise, especially for applications where reactions could be occurring on each stage. There is no limitation on the geometrical configurations used. Inlet and outlet lines for fluids and solids could be placed on each stage. Staging has already been successfully operated in the laboratory, both in concurrent and countercurrent flows.

Solids-air Jet Diameter

Another important aspect in the consideration of the jet action of the solids-air jet in the spouted bed is the contour of the solids formed by the upward-moving air. Experiments were performed on 4-in. and 6-in.-diameter split columns with wheat as the packing material. The orifice diameter in the 6-in. column was 0.25 in., while the 4-in. columns were investigated with 0.25-in. and 0.625-in. orifices. The variables of interest are the diameter of the solids régime (the diameter of the solids-air jet) and the distance up the column, which is termed here "bed level". Fig. 12 shows the type of curve obtained for a 6-in. column, 0.25-in. orifice and an 8-in. bed depth of wheat. The curves are oscillatory and they can be duplicated by a trigometric or series type function. It is quite unusual that the diameter of the solids jet should follow this function. One would expect a linear or a fractional power parabolic equation to satisfy the data. Tentative results indicate the equation for this type of flow to be

$$d_s = 0.95f - 0.198f^3 + 1.36 \times 10^{-3} f^5 \quad \ldots . (7)$$

The above equation was developed from the data collected on a 6-in.-diameter column with a 0.25-in. orifice and a total bed height of wheat of 8 in.

Minimum Spouting Velocity

GISHLER and MATHUR[1] published in 1955 an equation for minimum spouting velocity which was obtained empirically.

$$u_c = \frac{D_p}{D_c}\left(\frac{D_c}{D_c}\right)^{\frac{1}{3}}\sqrt{\frac{2g\,L\,(\rho_s - \rho_f)}{\rho_f}} \quad \ldots . (8)$$

If the system under study is thought of as the flow of a fluid through an orifice into a solids bed, a general equation similar to the GISHLER and MATHUR equation can be derived with a correlating coefficient from simple theory.

If the orifice is considered as section 1 and the top of the spouting bed is section 2, an energy balance can be placed across the system.

$$x_1 + \frac{u_1^2}{2g_c} + p_1 v_1 + E_1 + Q - W = x_2 + \frac{u_2^2}{2g_c} + p_2 v_2 + E_2 \quad \ldots . (9)$$

Conditions on Equation (9)

(1) There is no heat loss or gain in the system. $Q = 0$
(2) There is no work given to or taken from the system between points 1 and 2. $W = 0$
(3) The internal energy of the system is constant. $\Delta E = 0$

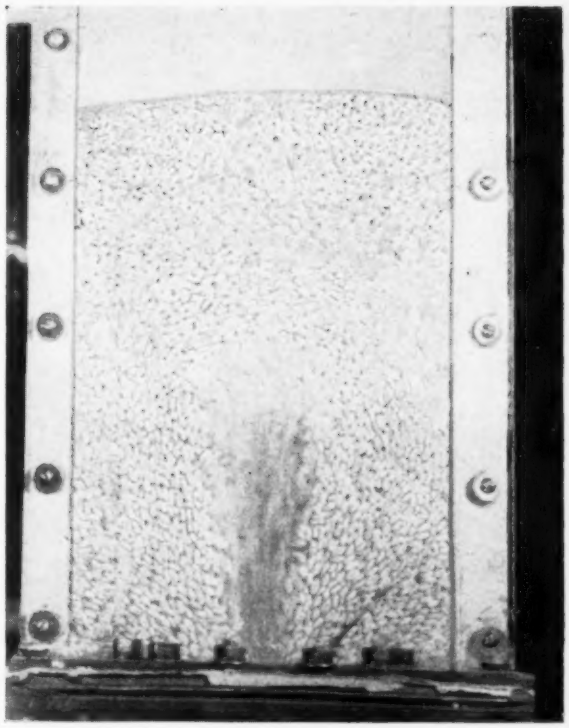

Fig. 8. Internal spout at maximum pressure drop.

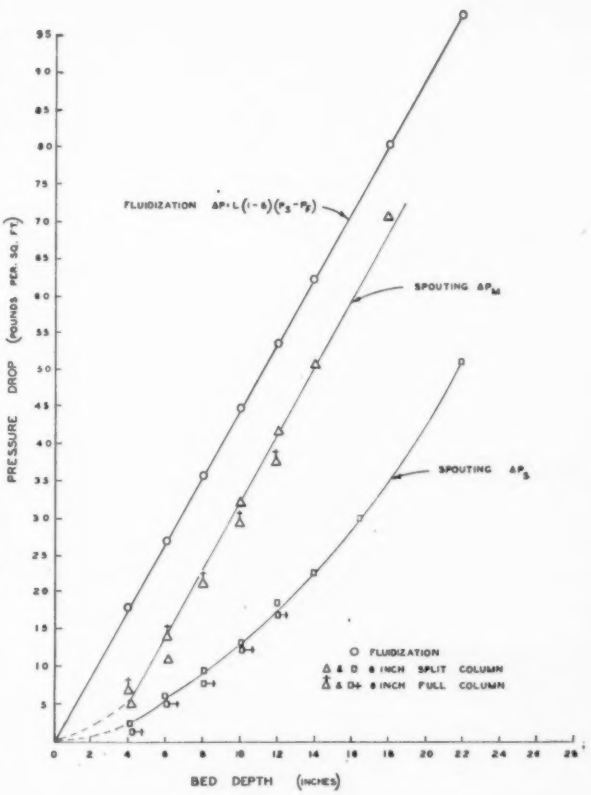

Fig. 9. Pressure drops of spouted and fluidized beds.

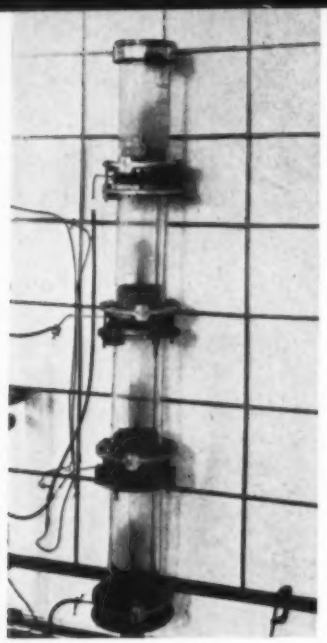

Fig. 10. Spouting in a four-stage column.

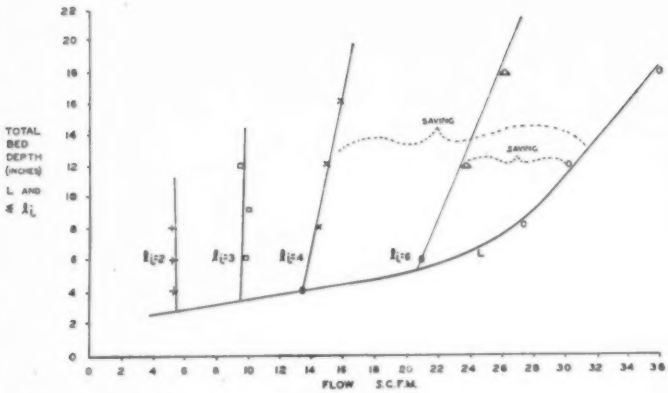

Fig. 11. Air requirements for single- and multi-stage operations.

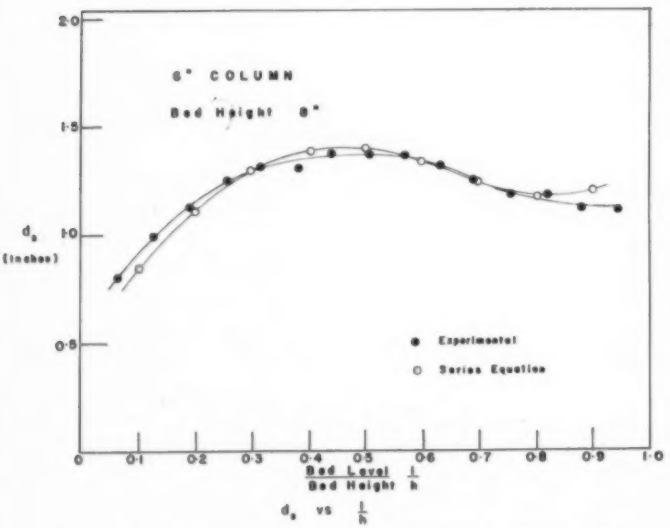

Fig. 12. Diameter of solids-air jet as a function of jet length.

Assumptions

(1) The specific volumes at 1 and 2 are constant; no density change.

$$\rho_1 = \rho_2 = \rho_f$$

(2) The fluid expands through the bed.

(3) The average velocity at (2) is negligible compared to the average velocity at (1). For incipient spouting conditions this is not an erroneous assumption, since $u_1 = 500\text{-}600$ ft/sec and $u_2 = 5\text{-}10$ ft/sec.

Also, let the datum line pass through x_1. Therefore,

$$x_1 = 0$$
$$x_2 = L$$
$$L = \text{bed depth.}$$

Incorporating the above conditions and assumptions into Equation (9) results in the following expression:

$$\frac{u_1^2}{2g_c} = x_2 + \frac{\Delta P}{\rho_f} \qquad \ldots.(10)$$

The bed depth expressed in feet of flowing fluid, x_2, is quite small compared to the other terms in the equation. As an approximation it can be omitted.

Hence, Equation (10) becomes:

$$u_1 = C_s \sqrt{\frac{2g_c\,\Delta P}{\rho_f}} \qquad \ldots.(11)$$

This is readily recognized as an orifice-type equation. However, C_s, the normal discharge coefficient, is not simple and probably a function of several variables.

$$C_s = f(D_p, \delta, D_o, D_c, \theta, \varepsilon)$$

These variables and their effect on minimum spouting velocities will not be discussed. Research is now being conducted on the relationship of the above variables on the coefficient.

Equation (11) gives the velocity through the orifice. This can be modified to obtain the superficial velocity through the column:

$$u_c = C_s \left(\frac{D_o}{D_c}\right)^2 \sqrt{\frac{2g_c\,\Delta P}{\rho_f}} \qquad \ldots.(12)$$

The term ΔP is the pressure drop in a spouting bed at the incipient condition. This can be expressed in two ways:

(1) Using the exact equation for spouting pressure drop which is Equation (5). However, the resulting expression is algebraically excessively complex.

(2) Using the fluidizing pressure drop equation:

$$\Delta P = L(1 - \delta)(\rho_s - \rho_f) \qquad \ldots.(13)$$

Note from Fig. 9 that the differences in the spouting pressure drop and fluidizing pressure drop curves are relatively constant. This is particularly true at the higher bed depths.

Substitution of Equation (13) into (12) results in an equation which is quite similar to the GISHLER-MATHUR equation.

$$u_c = C_s \left(\frac{D_o}{D_c}\right)^2 \sqrt{\frac{2g_c\,L(1 - \delta)(\rho_s - \rho_f)}{\rho_f}} \qquad \ldots.(14)$$

The latter equation is not a final expression by any means; the term C_s is complex and would have to be determined experimentally. The discrepancy between spouting and fluidization pressure drops would also be incorporated in this term.

ACKNOWLEDGMENTS

The authors wish to acknowledge their indebtedness to the National Research Council of Canada for their assistance in providing a grant for the above research work.

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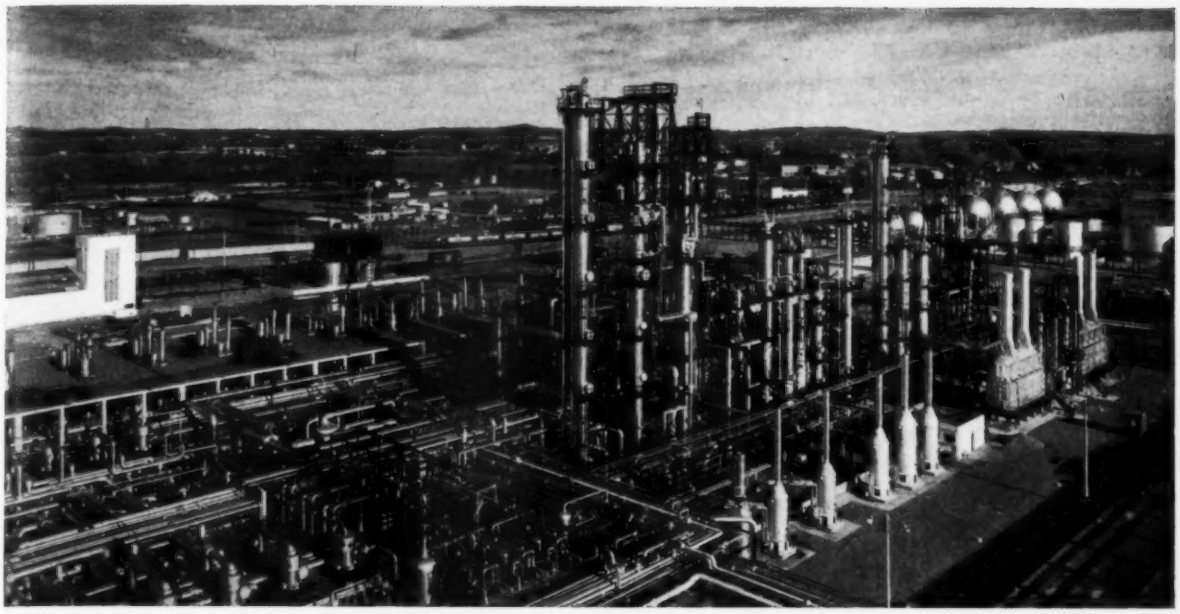

Fig. 1. General view of the low-temperature gasoline removal plant, second section, and ethylene production plant.

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LACQ NATURAL GAS PURIFICATION

A description of one of the largest natural gas treatment plants in the world, the by-products from which are expected to form the basis of an extensive petrochemical industry. The gas is first desulphurized by amine treatment to be followed by processes for the separation of such hydrocarbons as ethane, propane and butane; there will eventually be five sections to the separating plant, the purpose of the later sections being the production of light hydrocarbons. Sulphur recovery, another important feature of the plant, is carried out by a modernized Claus process, the ultimate tonnage (metric) being 4000 per day. The plant includes, in addition, sections for the treatment of hydrocarbons to make them of a saleable quality, for the manufacture of aromatic hydrocarbons, ethylene and fertilizers

FOLLOWING the bringing into production in April 1957 of the first stage of the Lacq natural gas purification plant by Société Nationale des Pétroles d'Aquitaine and the ironing out of teething troubles to be expected with so complex an installation, 1 million m³ of crude gas a day were originally being treated. By four further successive stages, the plant is expected to be capable of dealing with 20 million m³ of crude gas per day in 1961. When this final stage has been reached, the Lacq plant will be one of the most important in the world for the treatment of natural gas and an extensive petrochemical industry, based on the by-products of gas purification, is foreseen.

Gas collecting from the wells enters the plant at a pressure of 70 kg/cm² and at a temperature of between 15 and 20°C. Its composition is approximately as follows: 70 per cent methane, 5 per cent higher hydrocarbons and 25 per cent acids (including 15.30 per cent hydrogen sulphide and 9.70 carbon dioxide).

In view of this analysis, the purification plant has to perform three major functions: the separation of the hydrogen sulphide and carbon dioxide from the crude gas; the extraction of the propane, butane and petrol contained in the gas; and the extraction of sulphur from the separated hydrogen sulphide.

When the Lacq plant has attained its capacity for treating 20 million m³ of crude gas a day this year, it will yield each year the following major products: 4750 million m³ of purified gas which will be almost pure methane, 130,000 tonnes of propane and butane, 260,000 tonnes of petrol and 1,400,000 tonnes of sulphur. Both as regards French and European development, it will constitute an important project and employ techniques which are claimed hitherto to have been applied in European industry only on a small scale. The plant will employ about 1200 people, of whom half will work on eight-hour shifts and the remaining half the normal day shift.

Desulphurization of Gas

On entering the plant, the gas contains a liquid phase consisting of the condensate resulting from the expansion of the gas on leaving the wells and a gaseous phase, which is the crude gas proper. The liquid phase is removed in a separating plant which incorporates safety arrangements preventing the higher gas pressures at the wells from being passed into the works in the event of damage to the well heads. From the liquid phase is obtained a commercial petrol by dilution of the condensate followed by hydrodesulphurization. This is carried out in the petrol removal section of the plant.

Desulphurization is the first treatment to which the Lacq

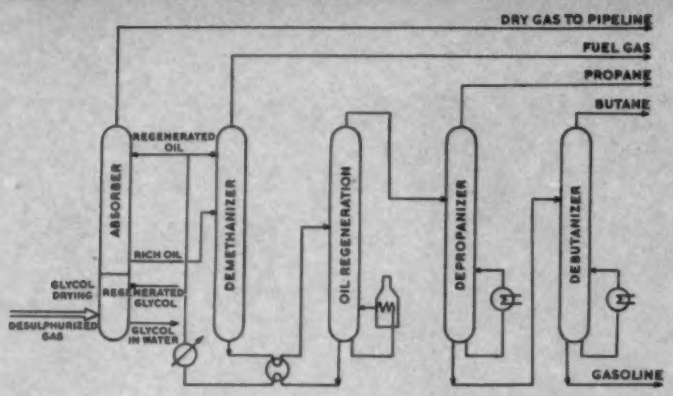

Fig. 2. Principle of system of recovery of products by absorption in oil.

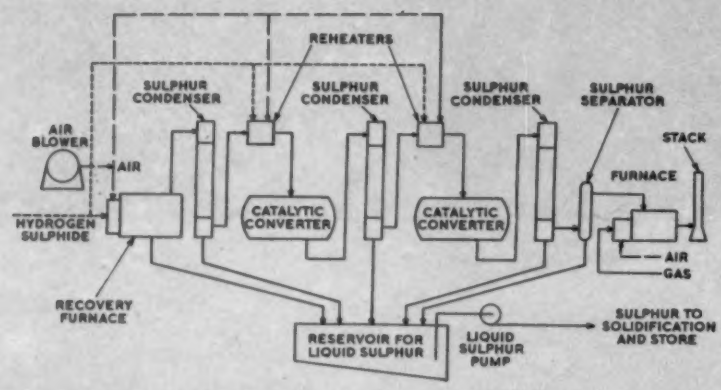

Fig. 3. Sulphur-producing unit.

gas is submitted; the extraction of the H_2S and CO_2 in the first section of the plant to be completed is done by a treatment with ethanolamines or weak organic bases which combine with the H_2S and the CO_2 weak acids to give salts which are separable at a high temperature. This is a process which is known in the U.S.A. as the Girbotol process.

The amine used is diethanolamine (DEA) in 20 per cent solution. Two columns are used in this process, one for washing the gas in contracurrent to the solution of ethanolamines and a second for regeneration of the ethanolamine solution.

In the crude gas/amine 30 tray contacting column, which operates under a pressure of 70 kg/cm² and at ambient temperature of 40°C, the gas flows in an upward direction to the top of the column during which the amine absorbs the acid gases almost completely. Almost free from sulphur compounds and carbon dioxide, the gas leaving this column is passed on to the petrol removal plant after undergoing mild treatment with caustic soda to remove completely the last traces of sulphur compounds and the mercaptans. This supplementary cleansing in contracurrent to caustic soda solution is carried out in a third tower and is made necessary by French regulations regarding the transmission and domestic use of gas which restrict the content of H_2S to the figure of less than 1.5 mg/m³.

Regeneration of the ethanolamine solution is effected by heat in the second 20 tray column, where the salts formed in the first column are broken down under a heat of 130-140°C and a pressure of 1.5 kg/cm². This reaction, which is the reverse of that in the first column, removes the acid gases from the amine solution which, after regeneration, is recycled to the contacting column. The acid gases, which leave from the head of the column, are sent to the sulphur-recovery kilns, the composition of the mixture then being: H_2S and H_2O 61.5 per cent; CO_2 37.5 per cent; hydrocarbons 1.0 per cent.

Other equipment in this section includes heat exchangers which permit the rich acid gas solution issuing from the contact tower to be preheated by the hot solution from the regeneration tower, and a pump which restores a pressure of 75 kg/cm² to the solution leaving the regeneration column.

Separation of Hydrocarbons

To separate the petrol, propane and butane hydrocarbons contained in the Lacq gas the first section of the plant uses a conventional method, while a new method is used in subsequent sections. In the first section, the hydrocarbons absorption in oil process is used, the sulphur-free gas, after having been dried, traversing an absorption column in contraflow to a low-temperature washing oil at −15°C. The gas leaving the top of the tower contains 96.5 per cent methane and 3 per cent ethane, etc., and is fit for commercial use.

Charged with hydrocarbons, the absorption oil passes through further columns, where it is submitted to fractional distillation. In the first column, the oil is freed of the small quantity of methane and ethane which it has dissolved. The fuel-gas mixture of these two gases is delivered to the central steam-raising plant, where it is used to heat the boilers. The absorption oil is then taken successively to three distillation columns where it is treated, together with the condensate from the separator preceding the desulphurization unit, to yield propane, butane and petrol.

The second section unit has been designed in order to augment the rate of recuperation of the light hydrocarbons, especially ethane, which is used to manufacture ethylene in an ethane cracking unit.

By this process, the temperature of the gas is lowered to

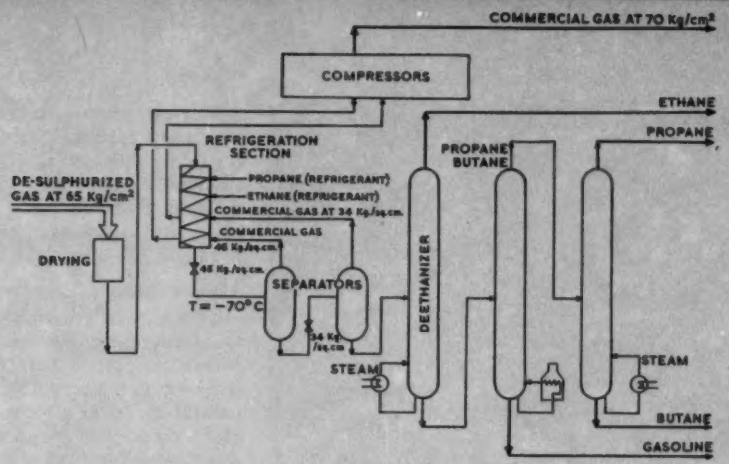

Fig. 4. System of gas separation by refrigeration.

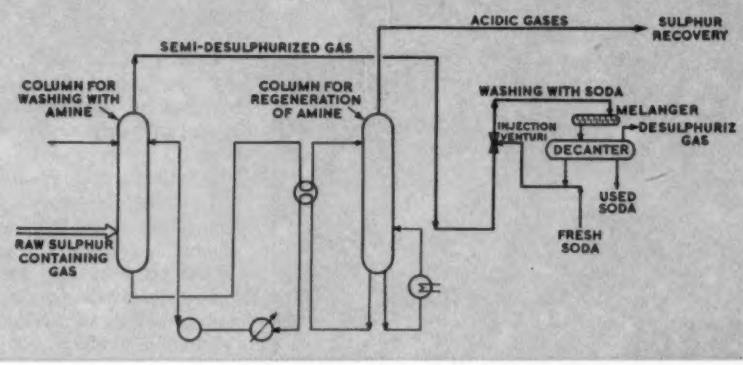

Fig. 5. Scheme of plant for desulphurizing by treatment with amines.

around −70°C, while its pressure is reduced from 70 kg/cm² to 45 kg/cm² and then to 34 kg/cm² by expansion. At this temperature and under these pressures, the gaseous fluid divides into a liquid and a gaseous phase, the latter representing the dry gas which, after recompression to 70 kg/cm², is passed forward into the pipes for delivery to the consumers or taken to underground storage. The liquid phase, being a mixture of ethane, propane, butane and petrol, is sent for separation into these fractions by distillation. By this method, relatively large quantities of ethane are obtained.

In this second section, the petrol removal plant consists of a drying unit using activated alumina; two gas-engined refrigeration units, one using propane, the other for ethane where the temperature of the gas is lowered by stages to −70°C; an assembly of expansion chambers in which the separation of the gas takes place at pressures of 45 kg/cm² and 34 kg/cm²; a compression station for the purified gas; fractionating columns for hydrocarbon separation; and caustic soda washing columns for the propane and butane.

For the third section of the plant a petrol-removing plant similar to that in the second section is used, while for the fourth and fifth sections the SNPA is installing a plant which, by the successive additions, can be adapted to produce light hydrocarbons to meet the country's needs.

Sulphur Recovery

The method used at Lacq for sulphur recovery has been derived from the well-known Claus process. On leaving the desulphurization unit, the acid gas contains 61.5 per cent H_2S and H_2O, 37.5 per cent CO_2, plus 1.0 per cent hydrocarbons. In the modernized Claus sulphur recovery unit the H_2S is transformed into sulphur by partial oxidation. During this treatment the following reactions take place:

$$H_2S + 3/2\,O_2 \longrightarrow SO_2 + H_2O + 124 \text{ cal.}$$
$$2\,H_2S + SO_2 \longrightarrow 3S + 2H_2O + 35 \text{ cal.}$$

giving an overall result of:

$$3\,H_2S + 3/2\,O_2 \longrightarrow 3S + 2H_2O + 159 \text{ cal.}$$

Under the modernized process it is possible to recover the heat from reaction in the form of steam. Conversion of the H_2S into S varies greatly with the temperature, which is strictly controlled. Maximum conversion takes place around 200°C. The viscosity of the liquid sulphur is at its lowest around 150° and increases considerably towards 190°C.

The first section of the Lacq plant is capable of producing 200 tonnes of sulphur daily; the second section incorporates three units producing a total of 800 tonnes a day; the third section includes two units producing a total of 1100 tonnes a day; while the fourth section, which will consist of two parallel flow lines, will have one unit for each line producing 1000 tonnes a day. The ultimate sulphur production will be about 4000 tonnes a day. All the units are designed on similar lines.

Each recovery system consists of a first-stage impact separator, a reaction furnace, an initial condenser, a catalytic converter and a second condenser, a second catalytic converter and a third condenser. These are duplicated in the second stage of the process.

The flow of acid gas passes to the horizontal reaction furnace where it is burnt, using air as the oxidizing agent. The furnace operates at a temperature of about 900°C. Although the sulphur recovery here is small, the heat from the reaction is used to produce steam in a rear tubular boiler in which the combustion gases are cooled to about 300°C. The steam is used partially to power the blowers which feed the combustion air to the furnace and partially to heat the exit conduits and pits for the liquid sulphur, the surplus being consumed in other parts of the Lacq plant.

Fig. 6. Sulphur being stockpiled at the port of Bayonne for shipment abroad.

Fig. 7. The third-section amine desulphurization plant.

On leaving the furnace the gas is cooled in the first vertical, tubular bundle type, condenser. Here, the sulphur in gaseous state is condensed, the gases moving forward to the horizontal, boiler-type catalytic converter, where they are brought into contact with activated bauxite arranged on a stainless-steel grille. Here, the second reaction takes place, part of the sulphur being in a liquid state and flowing directly into the steam-heated liquid-sulphur pits. The gas, still containing sulphur in vapour form, passes to a second condenser for liquid sulphur recovery, from which it passes to the second stage of the sulphur-recovery system which is similar to the first.

At the end of the treatment a separator stops the particles of sulphur left in the gas. Very little sulphurous material remains then in the gas, but to prevent any H_2S from being discharged to atmosphere, the gases are burnt in an incinerator, in which the H_2S is transformed into SO_2, before being evacuated by way of a 100 m high concrete stack.

Sulphur production in the various stages of recovery works out approximately at 25 per cent from the reaction-furnace condenser stage, 60 per cent from the first-stage catalytic reaction and 15 per cent from the second-stage catalytic reaction. More than 95 per cent of the sulphur contained in the acid gas is recovered, while the sulphur produced has a degree of purity in excess of 99.95 per cent.

Hydrocarbon Treatment and Ethylene Production

To make the propane and butane conform to commercial standards these are washed with caustic soda and dried before storage. Petrol, rich in heavy compounds, particularly of the mercaptan type, is treated catalytically on natural earths at a temperature of 380-390°C. All the sulphur compounds are converted to hydrogen sulphide. Soda washing and wet washing remove the hydrogen sulphide, yielding a petrol with a remarkable susceptibility to lead. Lacq petrol has, without ethylation, the properties of a good motor spirit, while very light ethylation gives it the properties of an excellent premium-grade fuel.

It is, in addition, very rich in aromatic hydrocarbons, especially toluene and xylene. SNPA has decided to produce benzene by hydrogenizing these aromatic hydrocarbons, hydrogen being easily obtainable from the methane. The benzene factory, at Lacq plant, will be able to produce 70,000 tons a year; it will be in operation at the end of 1961.

The ethylene production, which has been mentioned in connection with low-temperature process for separating ethane, petrol, propane and butane, has already started. The ethane cracking unit has a production capacity of 25,000 tons a year, which could be developed if necessary. This unit's working is particularly economical, because the purification of ethylene is done in the same unit which operates the extraction of ethane and other hydrocarbons.

Owing to the manufacturing of hydrogen, ethylene and benzene in the same plant, it is already possible to think of petrochemical productions as cyclohexane, for nylon, or styrene for polystyrene or synthetic rubber.

From hydrogen sulphide, which is found at Lacq in large quantities, SNPA manufactures such products as liquid hydrogen sulphide, mercaptans, thiourea and other thio-organic compounds.

Fertilizer Manufacture Planned

By cracking the methane, hydrogen and acetylene can be obtained, the former being a principal raw material for the manufacture of ammonia and, consequently, of nitrogenous fertilizers, and the latter being a very fertile source of organic syntheses. From acetylene many products can be made, especially plastics.

Already making nitrogenous fertilizers from natural gas, O.N.I.A. and Société dé Pierrefite, together with the Banque de Paris et des Pays Bas, have formed a new company, known as Azolacq, to manufacture fertilizers from Lacq natural gas and a factory has been constructed near to the Lacq gas fields for this purpose.

Two other development companies have also been formed to deal with eventual by-products from Lacq gas. They are Aquitainechimie, founded by leading chemical concerns, including Péchiney and St. Gobain, together with the Banque de Paris et des Pays Bas, to produce acetylene and methanol; and Methanolacq, formed by Aquitainechimie and Kuhlmann, for the manufacture of methanol and various other chemical products.

The cost of the first section of development of the Lacq gas purification plant involved an outlay estimated at about £6,000,000, in which are included a considerable amount of public funds.

To overcome the fissuring corrosion problem created by the inherent toxic and acid nature of the crude gas, special aluminium-chrome-molybdenum piping has been developed by French metallurgists for handling the crude material.

66.045.2 : 66.023.2

FILM HEAT-TRANSFER COEFFICIENTS IN VESSEL JACKETS

Published data in the literature concerning film heat-transfer coefficients for fluids flowing at very low velocities in jackets of vessels are examined. The usefulness of existing published procedures for calculating coefficients for oil and water flow is explored, using both published and some additional experimental data. Alternative approximate methods for rapid estimation of coefficients for water and calcium chloride brine are proposed

by F. R. WHITT

Fig. 1. Pilot-plant jacketed vessels at the Ruabon Works of Monsanto Chemicals Ltd.

THE jacketed vessel, by virtue of its adaptability for a variety of processes, is one of the most widely used pieces of equipment in the chemical industry. For example, glass-enamel-lined vessels, constructed basically of cast iron or mild steel, are used in great numbers in the fine chemical industry and can now be obtained in large sizes, and although it is sometimes feasible to equip them with corrosion-resistant metal coils, this deprives them of not only their essential simplicity but introduces the risk of polluting the reactants with metal. It is common practice, therefore, to rely upon the heat-transfer surface provided by the jacket alone, although this has low area : volume of vessel contents ratio.

For the purpose of chemical plant design, when making use of jacketed vessels, it is often necessary to estimate overall heat-transfer coefficients, particularly if the batch processing times are to be predicted for some unfamiliar process or for the scaled-up version of a known process. The design chemical engineer concerned must then make deductions from data in the general literature.

A few investigators have considered film heat-transfer coefficients for the stirred contents of reaction vessels.[1, 2] Boiling liquid film coefficients will probably be known to the designer from small-scale work on the particular materials. If the value of the overall coefficient is required for the case where a vapour is condensing in the jacket of the vessel, it is probable that the vapour film coefficient will be so much greater than that of the internal fluid being processed that any reasonable value used to estimate an overall coefficient will not introduce any serious error. When, however, a fluid is pumped through the jacket the fluid film may well be the major resistance to heat flow in the system.

Published data on heat-transfer coefficients for fluids flowing through the jackets of vessels are scarce; and most of what has appeared[3] indicates that one of the difficulties encountered in actual works practice is that the economic flow in a jacket is often in the streamline region (see also Fig. 9, Ref. 4). Other relationships of the variables have therefore had to be sought because the accepted equations, of proved reliability, for turbulent flow in tubes and annuli do not apply here.

In view of this situation, it was thought worth while to search the literature for relevant data on heat-transfer coefficients for fluids flowing in jackets of vessels.

Examination of Data in the Literature and Additional Data

(*a*) *Oil Heating*

The original experimental data of HANDS and WHITT[4] which gave rise to their Figs. 7 and 8 (p. 144 of Ref. 4) were re-examined in the light of the results published simultaneously by BARTON and WILLIAMS.[3] It was verified, by comparing the viscosities given in Fig. 5 of BARTON and WILLIAMS' work, with those determined experimentally for the Merilene oil used by HANDS and WHITT[4] that the oil used in each case was sufficiently similar to justify direct comparison.

Table I is the result of condensing HANDS and WHITT's experimental information in such a manner that direct comparisons can be made with predictions by the suggested design procedure (see Fig. 8 of Ref. 3). Some estimations of such relevant data as the temperature drop across the oil film and the mean oil film temperature had to be made (using the experimental determined overall coefficients and film coefficients). Additional assumptions based on other experimental data are given as notes to the tabulated data.

Evidently, quite reasonable values of the jacket oil film coefficients are estimated by the use of the BARTON and WILLIAMS procedure,[3] and calculated average overall heat-transfer coefficients are very close to those achieved in practice.

The oil-heated still and condensing equipment, from which the performance data were derived, has been described elsewhere.[7]

(*b*) *Water and Brine Cooling*

Water and $CaCl_2$ solution brine are fluids commonly used as heat-transfer agents in industrial practice. The work described in Ref. 3, although very comprehensive with respect to the flow of oils, makes only tentative suggestions

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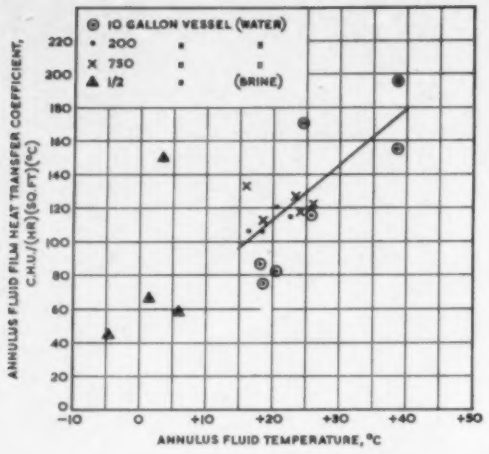

Fig. 2. Annulus fluid film heat-transfer coefficients.

for calculations with other fluids. Data are given by BROWN, SCOTT and TOYNE[2] and also by HANDS and WHITT[4] which can be analysed to give experimental data on film coefficients for water flowing in the jackets of vessels. Unlike the heat-transfer coefficients for the flow of viscous oil, which are by far the most important in deciding the value for an overall coefficient, water and brine coefficients are much higher and are much more on a par with the other coefficients. Hence in the latter case deductions based upon overall coefficients are more liable to significant errors. On this account the use of a condensing material, with a high coefficient, as one of the factors in the system is a desirable procedure. The work of BROWN *et al.*[2] refers to stirred water in the inner vessel whereas the other data of Ref. 4 were obtained from steam condensing inside the inner vessels, which heated water flowing through the jackets.

(1) Water Flow in Jackets

From the work of the investigators mentioned above some conclusions have been drawn on the magnitude of the water film heat-transfer coefficients for flow inside vessel jackets. These are summarized, for the three vessels involved, in Table II.

COLBURN and HOUGEN[5] and MCADAMS[6] present the following equation for streamline flow, about 0.1 fps, of water upwards inside a 3-in. diameter vertical tube:

$$h = 0.42t\,(\Delta t)^{\frac{1}{3}} \qquad \ldots . (1)$$

the temperatures being measured in °F.

The conditions of flow in the jackets of the vessels referred to above were similar, so the data of Table II were translated into a form suitable for using Equation (1). From Table III it will be seen that, for all three vessels, although there is some deviation from a mean value, the average value (0.455) for a constant, in a similar form of equation to that given as (1), is close to 0.42. It appears, therefore, that Equation (1) could be used to estimate film heat-transfer coefficients for water flowing at low rates in jackets.

BARTON and WILLIAMS[3] put forward a similar equation with a film temperature instead of a bulk temperature value which predicted coefficients lower than those actually obtained.

It will be noted that Equation (1) includes a variable, $(\Delta t)^{\frac{1}{3}}$, the value of which, in the experiments described elsewhere,[2, 4] varied only slightly, as would be common in general practice.

Therefore, the plotting of h against bulk temperature values of the water in the annulus seemed to offer a reasonable method of correlating the data, and results calculated accordingly are shown in Fig. 2 of this paper. The method gives approximate values of heat-transfer coefficients rapidly, given temperature conditions similar to those recorded in Table I.

(2) Brine Flow in Jackets

Experimental data for several brine-cooled vessels are described in Tables II and IV of Ref. 4. The values of the overall heat-transfer coefficients obtained show that the brine-side cooling fluid coefficients can be assumed to be similar in magnitude to those obtained with water.

One example is quoted in Table II of this paper, where the conditions of inner fluid, i.e., stirring rate and temperature, were such that a measured coefficient of the wall and inner fluid coefficients combination could be made, with some confidence, from a particular steam heating run.

The results of experiments carried out with a small stainless-steel reaction vessel (6 in. dia. × 9 in. high, with 7 in. dia. × 6 in. high jacket) are also recorded in Table II. This vessel was inverted and steam at atmospheric pressure was used inside the inner vessel to heat the brine flowing in the jacket. Rises in temperature of the latter fluid, of 9-26°C, were recorded. The experimental results are plotted on Fig 1 in order to allow comparison with the data obtained with water, already discussed. Examination of the brine flow data, on the lines of the method used to compile Table III, showed that Equation (1) would give approximate values of the brine coefficients.

BARTON and WILLIAMS[3] and MCADAMS[6] propose equations for estimating natural convection heat-transfer coefficients which, at first sight, seemed applicable to jacket fluid flow conditions, but as values of the brine physical properties required by the equations were unknown, they could not be used. It appeared also that the brine flows used were in the region lying between viscous and turbulent flow. The equations were therefore not strictly applicable to jacket fluid conditions.

Symbols Used

U = overall heat-transfer coefficient;
h = film heat-transfer coefficient;
ΔT = temperature difference, °F, jacket fluid/inner vessel contents;
Δt = temperature difference, °F, across film of fluid in jacket at the wall;
t = bulk temperature of water in jacket, °F;
FPS = feet per second;
C.H.U. = heat required to raise the temperature of 1 lb of water 1°C.

Heat-transfer coefficients in C.H.U./(hr) (sq ft) (°C) ≡Btu/(hr) (sq ft) (°F)

Subscripts

EXP = experimental value derived from work described;
CALC = calculated value derived from use of data in the literature;
B & W = boiling liquid film and heat-transfer surface wall.

Conclusions

Data published in the literature and other available information have been examined in connection with the estimation of heat-transfer coefficients for fluids flowing at low rates, 0.0134-0.178 fps, in the jackets of vessels. It appears that:

TABLE I—Heat-transfer Coefficients for Flow of Merilene Oil in the Jacket of a Vessel

Experimental Data and Deductions												Calculated Data (see Ref. 3, Fig. 8)					Fluid in Vessel (boiling)
Vessel				Temperatures, °C					Heat-transfer Coefficients			Heat-transfer Coefficients			Ratios		
Gal.	Material	Annulus width in.	Heat-transfer Surface sq ft	Oil in Jacket* Av.	Fluid in vessel	Difference Overall	Difference Across Oil Film	Oil Film	U_{Exp}	$h_{B\&W}$†	h_{OIL}	$h_{Calc}/(\Delta t)^{\frac{1}{4}}$	h_{Calc}‡	U_{Calc}	U_{Calc}/U_{Exp}	h_{Calc}/h_{OIL}	
50 Ref. 4 and 7	Cast Iron, glass enamel lined	¾	13	161	128	33	30	146	9	79	10.1	5.75	14.2	12.0	1.33	1.4	10 per cent thioacetic acid in acetic acid
			,,	157.5	100	57	46.7	133	14.5		17.7	5.68	16.1	13.4	0.9	0.98	Water
			,,	200	100	100	80	160	19.5		25.5	5.82	20.0	15.9	0.81	0.79	,,
			14	218	107	111	94 3	170	10.6		12.2	6.4	21.7	16.9	1.59	1.77	30 per cent formic acid in Water
			15	239	104	135	108	185	15.5		19.3	6.3	24	18.3	1.18	1.24	,,
							Estimated from other data.							Averages	0.96	1.23	

* Temperature fall of oil, range of 6–22°C. Oil flow in jacket: 0.025 fps Viscosity: 0.1–0.31 poise
† Derived from Ref. 4, Table IV, No. 1.
‡ 80 per cent values, as recommended in Ref. 3, from ordinate values $h/(\Delta t)^{\frac{1}{4}}$ of Ref. 3, Fig. 8.
Heat transfer coefficients in C.H.U./(hr) (sq ft) (°C).

TABLE II—Heat-transfer Coefficients for Flow of Water and Brine in Jackets of Vessels

Vessel				Fluid in Jacket			Heat-transfer Coefficients				Flow Rate of Fluid in Jacket	
Gal.	Material	Annulus Width, in.	Heat-transfer surface, sq ft	Bulk Temp. °C	Overall Temp. diff. °C	Fluid	$U_{EXP.}$	$h_{B\&W}$	h Water or brine	Fluid in Vessel	gal/hr	fps
10 (Ref. 4, Fig. 3)	Cast iron, glass enamel lined	½	5	39 39 24.8 25.8 22.3 20.6 18.8 18.2	61 61 75.2 74.2 77.7 79.4 81.2 81.8	Water	70 64 67 56 60 49 45 48	109*	196 156 170 115 133 80.4 76.1 86	Steam condensing 100°C.	60 60 85 105 155 167 205 250	0.0134 0.056
200 (Ref. 4, Fig. 9)	Mild steel, glass enamel lined	1 $\frac{7}{16}$	37	22.7 26.5 18.4 16.3	77.3 73.5 81.6 83.7	,,	52 53 50 50.5	95†	116 120 105 106	,,	290 670 680 880	0.028 0.05
700 (385-gal. charge) Ref. 2, Tables VII, VIII and XIII	Cast iron	1½	62	18.6 26.0 23.7 24.2 16.0	25.5 34.5 36.7 37.8 30.0	,,	64 67.1 68.3 66.2 70.3		112 121 125 118 133	Water cooling	1140 1454 2250 2265 2670	0.0285 0.067
½	Stainless steel	½	0.95	6 1.75 −4.85 3.6	94 98.25 104.15 96.6	Brine (CaCl sol 20%)	52.3 59.2 40.2 116	500	59.2 67.3 43.8 150.7	Steam condensing 100°C	26.6 33 46.5 46.5	0.088 0.178
10	Cast iron, glass enamel lined	½	5	+1.7	82	,,	64	85‡	257	Water 85°C	21.3	0.0477

* Derived from Ref. 4, Table II, Nos. 5 and 6
† Derived from Ref. 4, Table IV, Nos. 1–4
‡ From Ref. 4, Table II, No. 2.

TABLE III—Correlation of Heat-transfer Coefficients for Flow of Water in Jackets* (see Ref. 6, Equation (11))
Heat-transfer coefficients in Btu/(hr) (sq ft) (°F) ≡ C.H.U./(hr) (sq ft) (°C)

Vessel Gal.	Jacket Fluid Temperatures, °F				h	$\frac{h^*}{(\Delta t)^{\frac{1}{4}t}}$	Averages
	t Bulk	ΔT Overall	Δt Film	$(\Delta t)^{\frac{1}{4}t}$ Film		Film	
10 Ref. 4	102.2 102.2 85'5 78.5 72.0 69.0 65.8 64.5	109.2 109.2 126.5 134.5 130 143 146.2 146.3	38.9 35.5 49.2 63.1 60 87.2 86.2 70	347 331 303 313 281 306 290 266	196 156 170 115 132 80.4 76.1 86	0.565 0.482 0.560 0.367 0.467 0.263 0.262 0.324	0.411
200 Ref. 4	73 69 65 61.5	139 143 147 150.5	70.9 63.2 67 71.7	302 275 264 255	116 120 105 106	0.384 0.436 0.397 0.415	0.408
700 Ref. 2	65.5 78.5 74.5 75.5 61	45.9 62.1 66 66 54	26.3 34.4 34 28.6 38.4	194 255 241 229 190	112 121 125 118 133	0.575 0.475 0.518 0.517 0.70	0.557
			(Estimated)			Av.	0.455

(1) For the flow of Merilene oil, used as a heating agent, the procedure proposed by the authors of Ref. 3 gives close results to those found in practice from the operation of a 50-gal jacketed vessel. The range of heat-transfer coefficients investigated was 10.1-25.5 C.H.U./(hr) (sq ft) (°C).

(2) For the flow of water, used as a cooling agent, the equation proposed in Ref. 5 for upward flow in tubes appears to predict results which are reasonably close to those found experimentally for three sizes of jacketed vessel. The range of heat-transfer coefficients investigated was 76.1-196 C.H.U./(hr) (sq ft) (°C).

(3) For the flow of $CaCl_2$ brine, used as a cooling agent, the limited data available for two sizes of jacketed vessel suggested that heat-transfer coefficients of similar magnitude to those associated with water, under the same conditions, are obtained in practice. The range of heat-transfer coefficients investigated was 59.2-257 C.H.U./(hr) (sq ft) (°C).

ACKNOWLEDGMENTS

The experimental data, additional to that which has already appeared in the literature, were obtained during the course of plant operation in the now-closed Ministry of Supply Research Establishment, Sutton Oak, St. Helens, Lancs.

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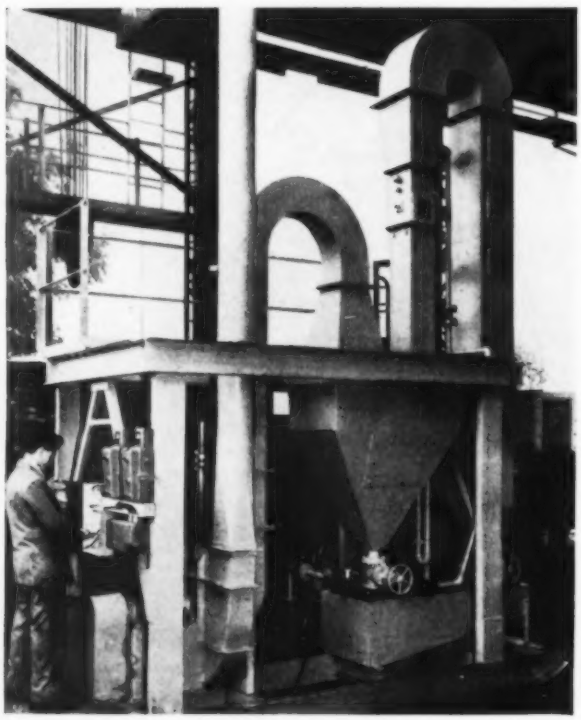
New Fume Cleaning Method Demonstrated by Pilot Plant

A TRANSPORTABLE pilot plant has been constructed to demonstrate the outstanding fume cleaning results obtainable by the Venturi Scrubbing process by Ambuco Limited who are a member of The Gold Fields Mining & Industrial Group.

These scrubbers are made under licence from Waagner-Biro and incorporate a unique process in which the fumes are caused to pass through *two* complete cones of water ensuring up to 99.6 per cent removal efficiency of most entrained solids in the range 5 to 0.01 microns.

This technique is applicable in such diverse applications as metal smelting and refining, chemical manufacture and sand grading plants. In fact, in almost every instance where dust laden fumes are produced the scrubbers are capable of eliminating the public nuisance which they cause, and of facilitating the recovery of the materials concerned should they be of sufficient value.



The working of the pilot plant can be clearly seen from the photograph. The fumes are drawn through the scrubber by the fan positioned on the left at the base of the exhaust stack. The dust laden fumes enter the scrubber through the ducting on the extreme right and are then drawn up the first vertical column. Here, whenever hot fumes are encountered, pre-spraying takes place to effect a temperature reduction.

The fumes are then drawn down the second column where, on a level with the inspection port, a spray forms a double cone of water at the top of the venturi. As the fumes are drawn through these cones, the entrained particles are separated from the fumes and carried in the water to the hopper beneath. The clean fumes pass through the top of the hopper and are expelled through the exhaust stack via the fan.

The entrained solids settle in the water in the hopper and may be drawn off periodically or continuously as required, and either disposed of with other liquid effluent or passed through a suitable filtration device for reclamation or disposal as required.

A unique feature of this pilot plant is that as it uses one full size venturi tube there is no scale effect and the efficiency demonstrated will be achieved on the subsequent larger installation. In practice the venturi tubes are assembled in groups to provide the required throughput, and as much as 200,000 cfm may be handled by one plant.

In many instances, Ambuco's experience will enable them to prepare a suitable installation without the need for carrying out pilot plant trials. But, whenever a new problem or a difficult set of circumstances arise, the pilot plant will be installed at the works concerned and the necessary trials carried out.

The fabrication of the pilot plant was carried out for Ambuco by A. A. Thornton (Teddington) Ltd., of Feltham, Middlesex.

The portable pilot plant which will be used to establish optimum working conditions for Venturi Scrubbers.

681.142 (73)

A Remington Rand "Univac" solid-state 80 digital computer installed in London.

PART I

SURVEY OF DIGITAL COMPUTER APPLICATIONS IN THE UNITED STATES

The basic operational principles and potentialities of modern digital computers are explained on a level understandable to non-computing personnel. Such knowledge is becoming increasingly desirable especially in chemical engineering, where the use of computers is growing rapidly. A survey of the most common digital computer types in the U.S.A. and their characteristics are given

by J. J. TABOREK

FROM the great inventions of the mid-twentieth century, the electronic computer has, more than anything else, affected the basic thinking and potentialities of practically every branch of science. With the help of computers and their breathtaking speed, exact solutions of problems are now possible which only a few years ago were unthinkable. The electronic computers which emerged in the first prototypes during the 1940s can be divided into two basic groups, the analogue computers and digital computers.

Analogue Computers

Analogue Computers are mentioned here for comparison purposes only. These machines make use of the relative ease of setting up electrical circuit analogues to simulate the more difficult conditions of, say, a heat-transfer or fluid-flow process. In such cases, the electric current simulates the flow, the electric potential the driving force (i.e., temperature difference or system pressure), electrical resistances represent the resistances to flow, and electrical capacitors represent the heat or energy storage potentials of the system. Arithmetic operations, disregarding their order of difficulty, are performed by single-purpose units such as adders, multipliers, integrators, vector resolvers, etc. These properties make the analogue computer a valuable tool for research-type investigations, especially for problems involving differential equations, but otherwise requiring relatively few algebraic operations. The results of analogue computations are continuously displayed in the form of curves, so that the effect of changing any variable and the transient behaviour of processes can be well followed.

The use of analogue computers is limited by: (a) the complexity of a problem through the availability of circuit equipment; (b) relatively large set-up time for problem changes; (c) rather poor accuracy of results and difficulty of numerical displays; and (d) limitation of speed by the use of electro-mechanical devices.

Digital Computers

Problems involving large data quantities or complex systems of equations are preferably handled by digital computers. Contrary to analogue computers, which perform complex operations like integration within a standard circuitry set-up, the digital computer deals with numbers in a way very similar to manual calculations or, for that matter, to an electric desk calculator. While the computation time for single operations of the desk calculator is quite good, the actual time delay in the solution of complex problems derives predominantly from two items: (a) the desk calculator is capable of performing only one operation before requiring new manual instruction and set-up; (b) intermediate results must be noted (stored) manually on a temporary basis and later re-entered into the calculator register.

It was realised in the early development stages of electronic computers that mere speed-up of actual calculation time would be worthless if not simultaneously accompanied by removing the human element from the instruction feed and introducing numerical storage for intermediate results to which the calculator would have an internal fast access.

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These later qualities, then, represent the essential characteristics of an automatic computer and distinguish it from other, non-automatic calculators, disregarding the actual computation speed of single operations.

Historically, the first machine which would correspond with our definition of an automatic computer was the IBM's Mark I (1943) with a 72-cell memory, but slow calculating speed. A considerable portion of the subsequent development was on the problem of computer memory with respect to its size and access time. One of these steps was the use of tiny mercury elements as storage cells for acoustical waves. The cathode ray tube as memory cell was the next developmental step and represented a substantial improvement. Several computers of this type were built in the United States, Europe and Russia, mostly for special and military purposes, with the IBM 701 as the commercially utilised application. Their speed was considerable (multiplication time about $\frac{1}{2}$ millisecond), but the memory storage was rather bulky and often limited to the range of 1000-2000 cells.

A big step forward was reached with the introduction of magnetic drums. Several machine types have been built on this principle in the United States and in Europe and many are still in production. Access time of the drum-type computer is, however, due to the rotational speed limitations of the drum, relatively large.

Ultimate development today seems to be the so-called magnetic core memory. Small in size and more dependable than any other previous type, it is being readily accepted for practically all new developments. The fast access time, together with other improvements, brought the typical multiplication time down to the range of 50 microseconds, while the compactness of the cores made possible memory storage size in the order of several ten thousands. Newest developments presently appearing on the market include the exclusive use of transistors, which considerably decrease the physical size of the computer and allegedly improve reliability by lowering the heat generation in the units. Prospective development trends indicate computing speeds about 100 times faster than the present fastest machine; i.e., about $\frac{1}{2}$ microsecond for multiplication and memory storage in the magnitude of 100,000 cells. The limitation seems to be only the speed of light.

Operation Principles of Digital Computer

While it may be considered unnecessary for the engineer preparing a problem for computer solution to be acquainted with the often confusing details of computer operations and coding, the knowledge of the basic working principles is in every case imperative. The digital computer consists of five basic units:

(1) *The input unit* represents the communication device between the computer and the outside world. The input material can be divided into (a) data, under which we understand all numerical values to be evaluated by the computer, and (b) the actual computer programme in the form of commands or instructions to be stored in the computer memory where it is kept ready for step-by-step execution.

The usual modes of input are (a) paper tape, (b) cards or (c) magnetic tapes. The speed of input becomes important on very fast machines and on cases, mostly business application, where a vast quantity of data must be handled. To minimise costly computer idling during input, the fastest input method, the magnetic tapes, is used increasingly. These can be prepared on so-called "off-line" equipment, thus eliminating the tie-up of the actual computer units.

(2) *Computer results output* can take various forms, especially (a) electric typewriters, (b) lineprinters (numerical or alphabetic-numeric) or (c) directly plotted curves. For similar reasons as on input, the speed becomes important on the fast and expensive machines, where again magnetic tapes as the fastest recording devices are used.

(3) *The storage or memory unit* consists normally of a large number of cells or computer "words" of specific length of digits, each of which can be filled with a computer instruction, a data word or an internally computed result or sub-result. This information, once stored, is preserved in the memory until "overstored" by a new one or "erased to zero". The memory in direct access is addressable; i.e., the numerical content of each cell can be directly called or specified by a command. The "access time" is the time which it takes to find a certain designated location in the direct access memory and carry the numerical content of that cell into the arithmetic unit for further processing. Magnetic drums have typical access times of about 100 microseconds, while the access time of the magnetic core memory is in the magnitude of 10 microseconds.

Magnetic drums are used as direct access memory units on the medium-fast computers. Their size is usually between 2000 and 4000 cells of 10 to 12 decimal digit words.

To extend the memory capacity of a computer, magnetic tape is frequently used as auxiliary memory. The information from the magnetic tapes must be transferred into the working memory before becoming addressable by the computer. The capacity of the magnetic tapes will reach into several million computer words.

(4) *The arithmetic unit* is, in effect, a very fast desk calculator. In close similarity both consist in principle of three registers. The first two will contain the "operands" or numbers involved in the arithmetic operations performed at that instant, while the third register, often called "accumulator", will contain the result of the operation. This result remains in the accumulator ready for the next instruction which may put it into storage or shift it into the operand register for subsequent use. Most computers have also a so-called "index register" which is used for automatic address modification in loop calculations.

Basically, the electronic computer knows only one operation, that is to add, but can perform this operation incredibly fast. Subtraction is reduced to addition of complemented numbers; multiplication is a series of subsequent additions; and divisions is a series of subtractions.

(5) *Control unit directs* the computer to perform desired operations in the correct sequence. The instruction to the control units is the sequence of "commands" prestored as programme in the memory. This particular feature, unique to the automatic computer, accounts more than anything else for its superior speed, as no human intervention is necessary to carry out a large sequence of arithmetic processes.

Number Representation

Whichever of the memory storage systems are used, the representation of numbers in the electronic computer is of "two-state" nature, i.e., a "yes" or "no" of an electric condition. For this reason many of the computers operate in a binary number system. If a decimal system is used, a second order of distinction must be added (e.g., that of position to the basic "yes-no" electric identification). The use of a decimal operating system has the obvious advantage of convenience of input and output while greater difficulties exist in the internal computer circuitry. Contrary, the binary system is simpler in the internal operations, but the necessary conversion between the decimal input and output and the binary internal system imposes certain difficulties and complications (e.g., use of decimal integers in binary system) even if the conversion process itself is done on modern machines quite automatically.

Another problem in the number representation is the location of the decimal (or binary) point in the computer "word". If this location is the same for all number "words", we speak of a "fixed point". The results of computation in

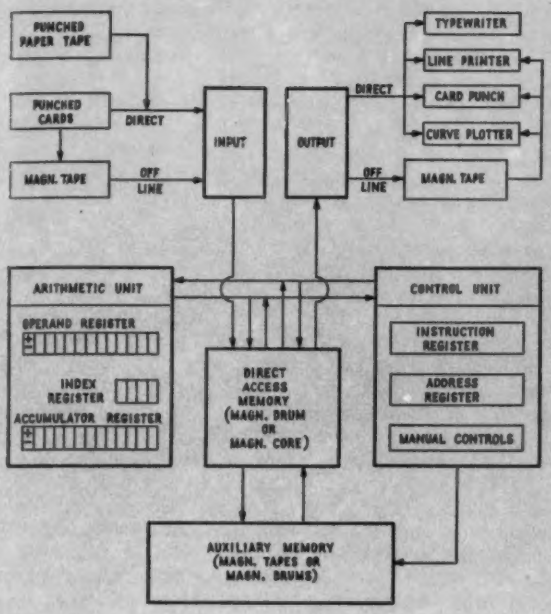


Fig. 1. Diagram of basic digital computer set-up.

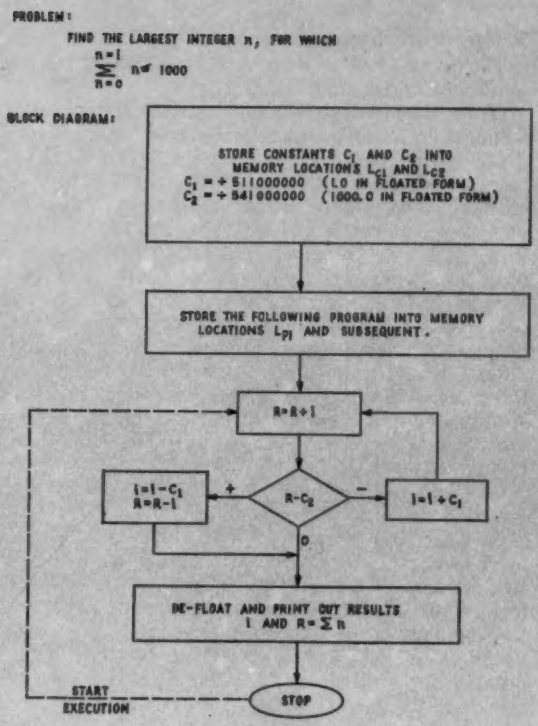


Fig. 2. Example of block diagram.

such cases are, however, subject to cumbersome "scaling" operations; i.e., locating the proper position of the decimal point of the results. For this reason most of the modern machines, especially those for scientific problems, are equipped with "floating point". In this case the location of the decimal point is indicated by attaching to each number a "floating exponent", which is a number resembling in significance the characteristic of logarithms. The floating exponent, however, decreases the useful number of digits in the machine word. The floating point operation requires also rather costly and complicated machine equipment, but offers conveniences which cannot be overestimated. Machines built for fixed point operations only can simulate the floating point by elaborately coded sub-programmes which, in turn, results in a considerably reduced calculation speed. For this reason a great majority of the modern computers built today in the United States has the floating point circuitry as standard or at least as optionally available equipment.

Programming and Coding Practices

The communication with the machine is in the form of "instructions" or "commands". These consist essentially of an "operating command" and the corresponding location or address, both in number form, occupying certain constant location in the machine word. For example (+0000 64 1000) would be interpreted as clear the operand register (symbol 64) and enter there the content of memory cell 1000. The most important commands will fall into one of the following categories:

(a) Input and output instructions such as: read cards into certain memory location.

(b) Arithmetic operations.

(c) Storage transfer between the registers and the memory.

(d) Control transfer instructions, which can be "unconditional" or "conditional". The latter usually depend on the relative magnitude of two numbers, resulting in two or three (+, −, 0) different control address transfers.

In addition to these basic command types, most modern machines have commands for the utilisation of the index registers which can direct the repetition of loop operations, modifications of addresses, etc. Altogether an average computer will have around 100 commands. The coding by such complex systems becomes quite difficult and chances for errors increase. For this reason automatic coding systems were developed, of which probably the FORTRAN for the IBM 700 series became the most complete and efficient one up to date. Further, it may be pointed out that the more complicated and composed algebraic functions like trigonometric and hyperbolic functions, natural and decimal logarithms, etc., must be developed in the computer from sub-routines; i.e., programmes representing the elementary development of such function. Despite this seemingly complicated process, the computer speed is so high that the calculation of, say, a trigonometric function with eight-decimal-digit accuracy should not take more than a few milliseconds on a core memory machine.

Programme Development

The development of a problem for computer solution can be divided into distinct stages:

(1) *Problem Analysis*—The mathematical (or engineering) formulation of the problem in equation form.

(2) *Programming*—The results of step (1) must be adapted to suit basic computer operational logic. This will include changes to the original mathematical form so that the flow of subsequent operations would permit most efficient use of the available computer commands. Repetitive portions of a programme will be formulated into "sub-routines". Further, decision must be made of input and output forms, probable requirements on memory size estimated with respect to the eventual need for the use of magnetic tapes. After this preparation, the original mathematical form of the problem may be considerably distorted. The result of such preparation is the so-called "block diagram", in which the computer operation steps, decisions, loops, etc., are clearly shown (Fig. 2).

(3) *Coding*—From this block diagram form of the programme, the actual coding is done.

(4) *Check-out*—Experience has shown that, even in the most carefully programmed problems, there will be a certain percentage of errors, which may include programming logic, actual coding, data preparation or the card punching. For this reason, the subsequent processing of a problem is the check-out, which is an actual computer run of a sample problem for which results are known, can be estimated or calculated by manual methods. To facilitate the check-out as well as to guard against the undetected and possible future data errors, a good programme may include self-checking features, strategically located in the programme. If physically impossible conditions have been created, calculation will be stopped and the accumulated results printed out. Errors inherent in the reliability of the electronic machine equipment will also occur, but only seldom will this affect the accuracy of the results. The reason is that a malfunction of the computer will result in a complete breakdown, or such an error generation that commands themselves will be completely distorted, rather than in a random error in some arithmetic operation.

Computer Installations

Presently in the United States there are over 3000 computer installations of the small and medium size class and several hundred of the large type. Aside from military problems, the typical computer applications can be divided into two basic groups: (1) business type problems, including such operations as stock inventory, re-ordering, wages, accounting, insurance records, banking, etc., and (2) scientific problems in which the atomic energy, aircraft and process industries are the leaders. According to these two application groups, the often-quoted division of the commercial computer is into "scientific" and "business" types. The business applications usually need very large memory storage (for inventories, accounts, etc.) with only a limited number of commands used. Contrarily, the scientific computer should have floating point and a large number of commands to permit the often complicated arithmetic operations and decision making. Furthermore, and especially for the very fast computers, only a few users will be able to feed a sufficient quantity of problems to keep the computers busy with a single-type problem. The cost of computer time, however, decreases the more their potentially available time is utilised. For this reason the tendency is toward the use of computers applicable for both business and scientific problems.

A majority of the computing installations, especially in the large class, is operated on a rental basis rather than outright purchase. This protects the user from obsolescence and provides other advantages of the capital investment. The rents, very roughly, amount to about 2-3 per cent of the purchase price per month at eight-hour/day of actual operation, including maintenance by the computer manufacturer. Extensions of this operating period beyond the minimum eight-hour shift is available at cheaper rates.

The selection of a digital computer will naturally depend on the type of problems to be solved. The following considerations will, however, have more or less general validity:

(1) *Size of addressable memory* will be the primary limitation to the size and complexity of a problem. Magnetic tapes can extend the addressable memory by alternately storing and overstoring its content. This process is, however, relatively slow. The economic break point in favour of larger addressable memory is reached if the cost of the computer time with small memory and tapes would become greater than the cost of a computer with larger addressable memory. It is the experience of the writer that the minimum computer size for scientific problems of average size should be 4000 words with two magnetic tape units. The largest installations at present have 32,000 words of addressable memory and 10-20 magnetic tape units, each of 400,000 words storage. The newest developmental trend in this respect is a memory which can be enlarged (in steps of, say, 4000 words) as the need arises. In this way, machine cost is saved in the initial stages of computing activities development, while the computer does not become obsolete as larger problems become feasible.

(2) *Computer speed* is of importance at least in one respect. It will determine the problem volume which can be handled. This problem must be decided on an economic basis. Comparing the cost of medium-speed and high-speed computers we will find that, generally, the working potential of the high-speed machine increases more rapidly than its cost. In other words, the fast computer is more economical, provided that the work load has reached a certain minimum. Beyond such limit, the fast computer leaves still a certain reserve in the addition of another shift operation while the potential of the slower machine has been exhausted.

The Most Widely Used Digital Computers in the United States

Small-size Computers

The number of manufacturers entering the computer field is steadily increasing with a correspondingly confusing number of models, types and variety of peripheral equipment. An attempt will be made here to list some of the computers presently manufactured in the U.S.A., selected mainly on the basis of number of installations.

LGP-30

This is a small, desk-size computer of limited scope and speed with punched paper tape input and output by electric typewriter. The main application appears to be for direct use of engineers on modest size problems. The programming is very simple, including only 16 commands. No floating point equipment is available, but can be simulated by a floating sub-routine, which naturally slows the calculation speed.

The memory is a magnetic drum of 4096 machine words and 2-17 milliseconds access time. Fixed point additions require 260 microseconds and multiplication or division 17 milliseconds.

The computer sells for $50,000, and about 400 are in operation.

Manufacturer: Royal McBee Corporation, Port Chester, New York.

Bendix G 15

This machine is a small magnetic drum (2176 words) computer of medium speed (0.5 m sec. access time) but has a variety of peripheral equipment, including magnetic tapes,

which make its use more flexible. Automatic compilers are also available. The sale price is around $50,000 for basic set-up and about 300 installations are in operation.

Medium-size Computers

Datatron 205

This computer is a medium-speed, medium-price, magnetic drum (4080 words) computer, used for engineering and business applications. It has optional floating point equipment and auxiliary storage of up to 10 magnetic tape units, each tape reel containing 400,000 words. Input is by cards or punched paper tape. The relatively large access time of 850 microseconds is speeded up by the incorporation of an 80-word rapid memory where the access time is one-tenth of the main memory time. This improves the access time, but also creates certain coding difficulties in the otherwise very good and simple programming system. The addition time is 1.85 milliseconds; multiplication and division takes about 8-10 milliseconds. There are 71 instructions and a good sub-routine library. The sale price for an average installation is about $250,000. Some 100 machines are in operation.

Manufacturer: ElectroData Division of Burroughs Corporation, Pasadena, California.

IBM 650

This medium-price and medium-speed magnetic drum computer has floating point as optional equipment. This computer is probably the most widely used at present, with about 2000 installations, including business and scientific operations. The memory is a magnetic drum of 2000 words and access time of about 100 microseconds. Latest versions of this machine have a 4000-word drum and a 60-word rapid access operating memory (cores), which is definitely an improvement especially for scientific problems. Auxiliary memory includes magnetic tapes (up to 10 units) and a RAMAC data file system (40,000 storage words) for business application. The operating time is 700 microseconds for additions and 2.4-20 microseconds for multiplications. Programming includes 96 commands and an extensive library of sub-routines is available. Also available is an automatic programming system, FORTRANSIT.

The machine sells at about $200,000 for an average installation.

Manufacturer: International Business Machines Corporation, White Plains, New York.

Datatron 220

This is an upper-medium class computer with core storage memory of 2000 to 10,000 words, and 10 microseconds access time, suitable for business and science. The auxiliary memory as magnetic tape units have capacity up to 55 million machine words which can be loaded at a speed of 2400 words/second. Programming is similar to the 205 version. Addition time is 185 microseconds, multiplication 2 milliseconds.

Several installations are in operation. The cost of an average installation is about $500,000.

Large-size Computers

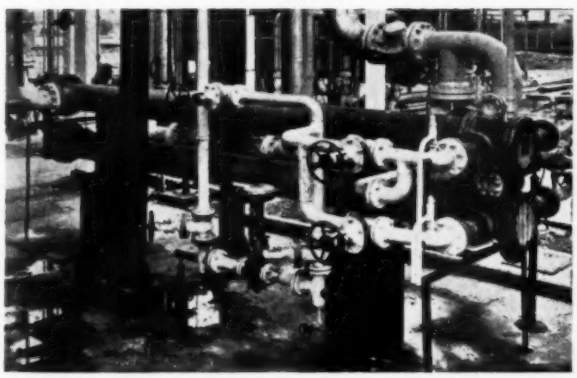
This class is characterized by the highest computation and memory access speeds, but also by the size of the addressable memory, which will be in the 10,000-32,000 class, and widest selection of the peripheral equipment. The high speed and high cost of these computers make the use of rapid input and output methods, as well as the use of elaborate automatic programming systems, a necessity.

Many recent and apparently successful entries in the large computer field (CDC 1604, Philco 2000, RCA 501, Univac II, Honeywell 800) reflect increased interest by customers, most of which are enlargements from initial medium-class computer installations which became overloaded.

With respect to number of commercial installations, the field is dominated by the IBM 700 series, of which several hundred are presently in operation.

The representative machine is the IBM 704, a scientific computer with 32,000 core storage and 12 microsecond access time. Recent trend is toward the IBM 7090, which is the scientific-business version of the 704, fully transistorized and has an effective computation time improvement of about 1:10. Very fast magnetic tapes, wide selection of peripheral equipment and probably the most effective automatic compiler, the FORTRAN, are available. A typical installation will rent for about $50,000-70,000 monthly.

Aluminium Heat Exchanger Successful



WHAT is probably the first all-aluminium heat exchanger to be installed in a refinery in Britain has recently been inspected and found to be in good condition after its first year in service. The unit, made by Wellington Tube Works Ltd. and installed in the gas purification plant of Mobil Oil Co.'s refinery at Coryton, has been found not only to have resisted the attack of the hydrocarbon gas—containing 10 per cent H_2S and a trace of water vapour—which passes through the shell side at 220°F, but it has also successfully withstood the notoriously corrosive properties of Thames Estuary water which is passed through the tubes at 6 ft/sec. Some light pitting, found on the outside of the tubes, is due to carry-over of particles of rust from other sections of the plant.

The use of sea water as a cooling agent led to the adoption of internally-clad tubes, a product of Alcan Industries Ltd. who also supplied material for the tube sheets and flanges. The Noral 3S alloy tubes are clad with Noral 72S which is metallurgically bonded to the inner surface. The 72S alloy (1 per cent Zn, remainder aluminium) is anodic to the 3S alloy under the recommended conditions of service and it therefore acts sacrificially in protecting the tube against corrosion. The use of this type of clad tubing is considered to be advisable in applications using natural and untreated waters, including sea water, that may cause pitting of unclad aluminium tubing. The effectiveness of the cladding is well demonstrated in this case.

The condition of this unit as a whole after twelve months in service demonstrates the value of aluminium alloys for use in plants that are required to handle oil products, H_2S or sea water, such as oil refineries, chemical works and gas works.

DX SUNRAY SOLVENT DEWAXING UNIT

PRIOR to recent extensions, the DX Sunray refinery, Tulsa, Oklahoma, had three small dewaxing units for lubricant manufacture; these are now to be scrapped and replaced by a new dewaxing unit, the second largest of its kind ever to be made. The original units previously restricted wax production to a limited amount of fully- and semi-refined paraffin waxes and a crude microcrystalline wax. The new plant will permit manufacture of eight fully-refined wax products.

The works are in three main sections, which together form an integrated unit designed for central control. The first stage produces dewaxed lube stock; the second charges the crude wax from stage one and de-oils and fractionates this to give a nearly pure product wax, and a third stage removes the final traces of oil or soft wax.

Heat Exchangers

Other equipment includes 28 double pipe heat exchangers; this type of cooler is designed to chill oil containing large proportions of wax, to crystallize the wax in the presence of a solvent and to maintain a uniform flow of solids and liquids; the total heat load is 40 million Btu/hr.

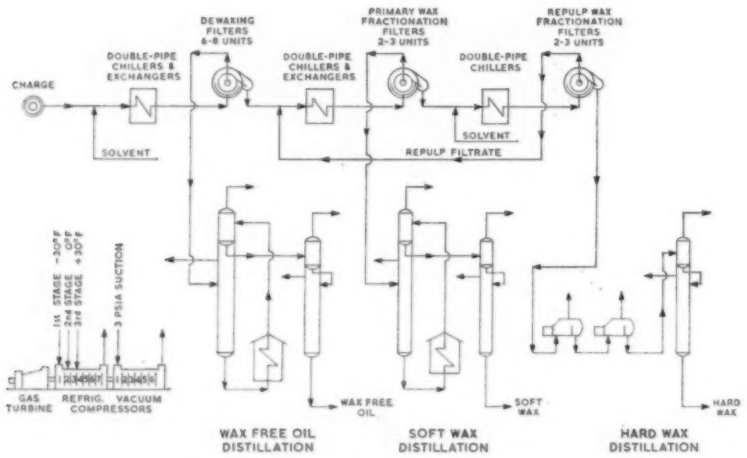
Filters

Twelve dewaxing filters of the latest design are installed for separating wax from solvent; each has an effective area of 700 sq ft, and handles approximately 4000 barrels of oil and solvent and 30-45 tons of wax a day.

Capacities

Service requirements for the whole dewaxing plant are:

Cooling water	12 000 gal/min



Solvent dewaxing plant, Tulsa Refinery

Integrated Power Users

In the design of the entire installation, a prime consideration has been efficient use of the various services, and the production of the major portion of the power requirement by a single large machine.

This latter, a noteworthy feature of the plant, is driven by a 7500-hp turbine with a consumption of 100,000 cfh of natural gas (c.v. 1000 Btu/cu ft), and itself drives a 2000-ton refrigeration compressor and a vacuum pump-compressor. At full load the turbine exhaust gases generate some 32,000 lb of steam an hour in a high-pressure boiler.

The refrigeration compressor, which uses propane as refrigerant, is the greatest consumer of energy; it provides coolant at −30°F, 0°F and 30°F.

The vacuum pump-compressor has the dual duty of circulating inert blanket gas throughout the system and at the same time generating the vacuum required by the rotary dewaxing filters. This section circulates 19,000 cu ft of inert gas a minute at a vacuum of 3 lb per sq in abs.

This dual system offers a saving in both first and operating costs.

Electricity (at 2300, 440, 110/120 V)	1050 kW
Steam	32,000 lb/hr
Natural gas	185,000 cu ft/hr
Instrument air	110 cu ft/hr

Layout and Control

A compact plant layout enables the entire dewaxing works to be contained in an area of only 230 ft by 310 ft. The site is divided into a refrigeration area, a filter area and a solvent recovery area, and the operations are controlled from a central control room.

Because of the heavy equipment used, plant has been supported on 600 concrete piles.

Production

Output from the plant varies from stock to stock; the lightest neutral charge is 11,000 bls a day and the heaviest bright stock reduces the charge to 6800 bls a day. A typical daily output is 6800 bls of dewaxed oil, soft wax 300 bls, and production wax 900 bls.

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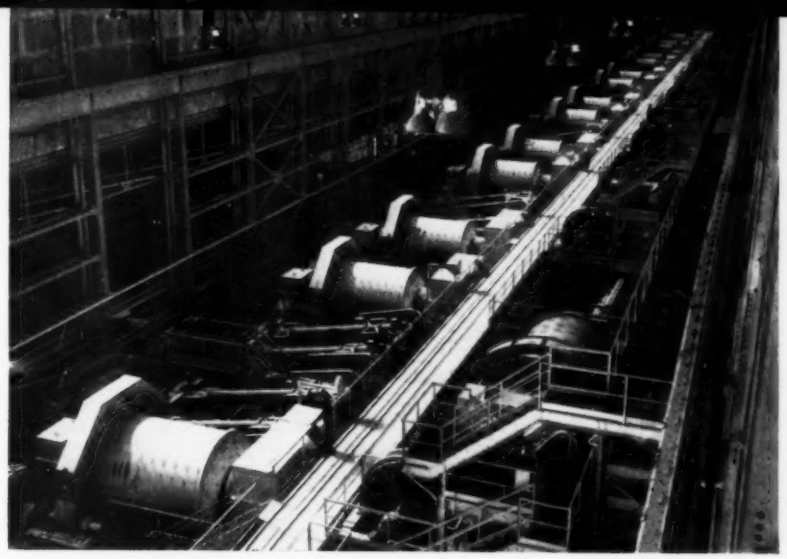

Fig. 1. Fourteen 800-hp ball mills installed at Southern Peru Copper Corp.'s concentrator, Toquepalo, Peru, grinding 30,000 tons of copper ore daily.

PART II

CRUSHING AND GRINDING CALCULATIONS

The concluding part of this article is concerned with a number of factors affecting the grinding process and the life of equipment, such as the fraction of mill volume occupied by the grinding charge, the quantities of rods and balls to be contained in a mill, wear of mill and grinding medium, and mill speed in terms of the critical speed. The effects of mill diameter, of downward slippage of ball charge, ratio oversize:feed, upon performance and power consumption are discussed. Open-circuit multiplication factors are given for converting closed-circuit work values to the open-circuit values and, finally, correction factors are given for work index variations which arise when laboratory grindability and impact crushing tests give different work index values.

by FRED C. BOND

Metal Wear

METAL wear is usually the second largest single item of expense is conventional grinding, and in wet-grinding installations it may approach or even exceed the power cost.

Metal wear is commonly expressed in lb/ton crushed or ground. However, variations in feed and product sizes and in work index are eliminated by expressing metal consumption as lb/kWh, including rejected worn parts; it can be obtained from the pounds of metal consumed per ton crushed or ground and the kWh/ton.

The pounds of metal both worn away and scrapped as worn parts varies with the abrasiveness of the ore and the abrasion resistance of the metal. The average values from a large number of mills with ordinary mill linings and grinding media, grinding wet a large range of siliceous ores, are as follows:

Mill Type	*Rod*	*Ball*
Media: lb/kWh	0.21 rods	0.14 balls
Lining: lb/kWh	0.026	0.020

The metal wear in dry grinding averages about one-seventh that of wet grinding the same material. However, many of the materials ground dry are softer and less abrasive than those ground wet. Ball coating in dry grinding can reduce the metal wear still further.

Well over half of the metal wear in wet grinding results from corrosion, or dissolution from the active nascent metal surfaces continually being produced in the mill. For this reason the metal savings resulting from the use of hard alloy mill linings or media are usually greater in dry grinding than in wet grinding.

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Abrasion Tests

Abrasion tests to indicate metal wear are made as follows:[10] 400 grams of $-\frac{3}{4} + \frac{1}{2}$-in. particles of the material to be tested are placed in a rotating drum for 15 min. The drum showers the rock through a rapidly rotating impeller contained within it. The impeller rotates at 632 rpm and consists of a $3 \times 1 \times \frac{1}{4}$ in. steel paddle with 2 sq. in. exposed to wear, machined of SAE 4325 steel hardened to 500 Brinell. The grams of weight lost by the paddle after impacting four successive 400-gram batches of rock for 15 min. each is called the abrasion index and designated as *Ai*. The combined product of the four 15-min. periods is screen analysed; it averages 80 per cent passing 13,250 microns.

Paddles of special alloy steels and cast irons can be tested with a standard abrasive material to determine relative wear resistance of the metals.

The average *Ai* values of some typical materials from 125 tests are listed in Table IIA in the appendix. A firm correlation with actual wear rates in crushers and grinding mills has not been made as yet; however, it is apparent that the abrasion index variations shown in Table IIA are much greater than the variations to be expected in the metal wear rates in commercial machines. It is observed that any correlation between the work index and the abrasion index is very slight.

Preliminary indications are that in wet grinding the pounds of balls per kWh equals $(Ai + 1)$ divided by a

number which ranges from 6 to 9, and liner wear is about one-eighth of ball wear. For wet rod mills the divisor ranges from 4 to 6, and liner wear is about one-seventh of rod wear. Wear in dry grinding is about one-seventh of wet grinding. The average metal wear in crushing is roughly comparable to the liner wear in wet grinding.

Volume of Grinding Charge

The fraction Vp of the total interior mill volume occupied by the grinding charge can be found by Equation (15), where D is the inside diameter and Q is the vertical distance down from the inside top of the mill to the levelled grinding charge: Q should be the average of measurements at the centre and both ends of the mill.

$$Vp = 1.13 - 1.26\,Q/D \qquad \ldots.(15)$$

The weight of the grinding charge can be calculated from D, Vp, and the inside length of the mill.

Loose round balls without breakage weigh 290 lb/cu. ft, loose rods 390 lb and silica pebbles 100 lb. Measurements of the weight of steel balls contained in a cubic foot box are usually less than 290 lb because of the increased void space at the sides of the box, and the weight contained decreases as the ball size increases. For accurate measurements the smallest dimension of the container should be at least 20 times that of the largest ball. Broken balls can reduce the specific weight to 280 lb/cu. ft, and broken rods to 340 lb. The specific weight of both ball and rod charges can also be reduced by a content of hard particles of the material being ground.

Tons of new balls Tb contained in a mill are found approximately from Equation (16), and tons of new rods Tr from Equation (17).

$$Tb = Vp\,D^2L/8.4 \qquad \ldots.(16)$$

$$Tr = Vp\,D^2L/6.8 \qquad \ldots.(17)$$

A charge of grinding balls contains approximately 40 per cent of void space, and rods in linear contact contain 20 per cent voids. Broken ore contains approximately 40 per cent void space, and weighs 100 lb/cu. ft multiplied by its specific gravity over 2.65. At 80 per cent solids or more the voids in a grinding charge of steel balls can contain 14 per cent of the ball weight in ore multiplied by $Sg/2.65$. A rod charge with the rods in linear contact can contain 7 per cent of the rod weight. However, both balls and rods are commonly forced apart in the mill and may contain more ore than these minimum amounts.

The per cent solids contained in the pulp within a wet grinding mill is ordinarily more than that entering and leaving the mill, since the water flows through the mill faster than the heavier particles of ore. This difference is increased in grate and peripheral discharge mills.

Critical Mill Speed

The theoretical critical speed Nc in rpm is the speed at which a particle of no diameter against the mill lining with no slippage would centrifuge. It is found from Equation (18), where D is the interior mill diameter in feet.

$$Nc = 76.6/\sqrt{D} \qquad \ldots.(18)$$

The fraction Cs of the critical speed represented by any mill rpm is found from Equation (19).

$$Cs = 0.01305 \times \text{rpm} \times \sqrt{D} \qquad \ldots.(19)$$

Tumbling mills are usually designed to revolve at a constant fraction of the critical speed. Increased speed increases the mill capacity and power draught, but also increases the metal wear and maintenance cost per ton ground. For conventional wet grinding ball mills more than 8 ft in diameter, with peripheral lifters and a ball charge of more than 30 per cent of the interior mill volume, the maximum practical mill speed is about 77 per cent of critical; for wet rod mills it is about 70 per cent of critical. Somewhat slower speeds are often found to be more economical.

Dry-grinding mills and pebble mills usually operate at about the same speeds as wet mills, with the maximum less limited than in wet mills.

Laboratory studies have shown that on the rising side of the mill each circular row of grinding balls slips downward with respect to the next outer row it rests upon, thus causing some grinding in this portion of the mill. A similar slippage is not observed in rod mills.

At speeds faster than 60 per cent of critical the smaller balls or rods in a grinding charge tend to concentrate with the pulp near the lining of a cylindrical mill, and the larger media are displaced toward the centre of the charge. Advantage is taken of this in ball mills to move the smaller balls toward the discharge end of the mill by spiral lifters trailing toward the mill discharge; or by making the mill shell slightly conical, with the smallest diameter at the discharge end.

Small-diameter mills are commonly operated at somewhat higher fractions of their critical speeds than are large mills, indicating that the proper mill speed is intermediate between a constant fraction of critical speed and a constant peripheral speed. An approximate empirical equation for the maximum practical rpm of wet ball mills, designated as No, is:

$$No = 57 - 40 \log D \qquad \ldots.(20)$$

Effect of Mill Diameters

At a constant volume fraction Vp the mass of the grinding charge varies as D^3. At a constant fraction Cs of the critical speed the peripheral speed varies as $\sqrt{D}$. It follows that the power input to a conventional tumbling mill theoretically varies as the interior diameter to the 2.5 power.

Measurements have shown that the wet fine grinding mill capacity varies as $D^{2.6}$. The diameter exponent increases slightly in mills operated under high impact conditions. Theoretically, the maximum exponent under reduction entirely by impact is 3.0.

Measurements have also shown that the power input exponent actually varies as $D^{2.4}$. The decrease from the theoretical 2.5 exponent probably results from energy from the falling balls or rods being transferred back to the mill shell on its down-going side. The actual diameter exponent per ton of grinding media is 0.4 instead of the theoretical 0.5.

The difference between the two observed diameter exponents of 2.6 and 2.4 is 0.2, which is the exponent defining the mechanical advantage of large-diameter mills. Mechanical efficiency increases as the interior mill diameter to the 0.2 power, and the kWh/ton required to grind decreases in the same ratio. Since the standard work index is based on mills of 8 ft interior diameter, the computed kWh/ton (W) by Equation (1) for any mill of D ft interior diameter should be multiplied by $(8/D)^{0.2}$.

Power per Ton of Grinding Media

The power input required in tumbling mills is calculated from the power required per ton of grinding media under the mill operating conditions. It varies with the fraction Vp of the mill volume occupied by the grinding charge, the fraction Cs of the critical speed, and the interior mill diameter D in feet.

Equation (21) gives Kwr, the mill input kW per ton of new grinding rods in conventional wet grinding overflow rod mills.

$$Kwr = D^{0.4}(6.3 - 5.4\,Vp)\,Cs \qquad \ldots.(21)$$

An accumulation of broken rods in the mill can reduce the actual power drawn by as much as 10 per cent.

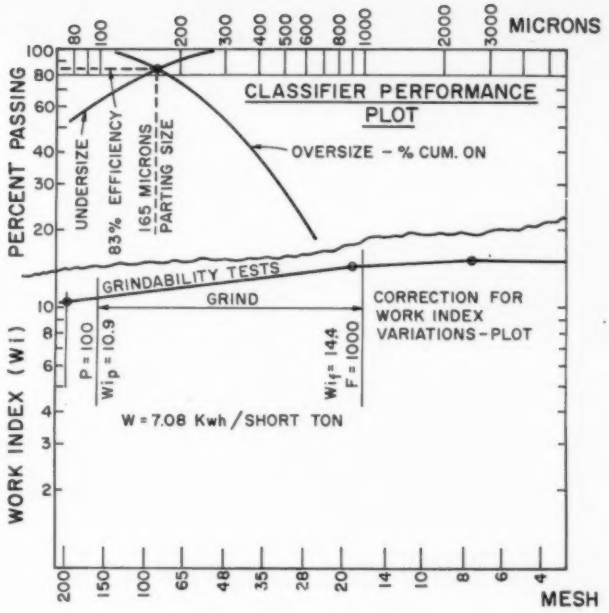

Fig. 2.
TOP: Classifier performance plot.
Oversize per cent cum. on plotted against undersize per cent passing. Intersection shows 83 per cent classifier efficiency and 165 microns parting size.

BOTTOM: Correction for work index variations. Grindability Tests—Wi = 14.4 *at* 14 *mesh.*
Wi = 10.4 *at* 200 *mesh.*
Grind in ball mill from 80 *per cent passing* 1000 *microns to* 80 *per cent passing* 100 *microns.* Wi_p = 10.9, Wi_f=14.4; *from Equation* (42) W=7.08 *kWh per short ton.*

Equation (22) gives *Kwb*, the mill input kW per ton of grinding balls for conventional wet-grinding ball mills using make-up balls larger than about one-eightieth of the mill diameter.

$$Kwb = 2.8\,D^{0.4}(3.2 - 3\,Vp)\,Cs(1 - 0.1/2^{9-10Cs}) \quad \ldots.(22)$$

For dry-grinding grate discharge mills *Kwb* should be multiplied by 1.08.

If *Qd* represents the vertical distance in feet from the inside top of the mill to the lowest discharge point, then

$$Vpd = 1.13 - 1.26\,Qd/D \quad \ldots.(23)$$

where *Vpd* is the fraction of the interior mill volume below discharge level. For a full low-level grate discharge *Vpd* equals 0.029. For wet-grinding grate and low-level discharge mills, multiply *Kwb* by $\left[1 + \frac{0.40 - Vpd}{2.5}\right]$.

Slump Correction

Large-diameter ball mills fed with small make-up balls lose power because of excessive downward slippage of the ball charge on the rising side of the mill, and this loss of power input decreases the mill capacity. An empirical slump subtraction quantity *Ss* is computed for wet overflow and grate ball mills by Equation (24), to be subtracted from the *Kwb* value of Equation (22). No subtraction is made for wet ball mills with $D < 8$ or for dry ball mills with $D < 10$. For dry mills with $D > 10$ the slump quantity to be subtracted from *Kwb* is three-quarters of *Ss* as found by Equation (25), where *B* is the diameter of the make-up balls fed in inches.

$$Ss = \left(\frac{12D}{10B} - 8\right)^{\frac{1}{3}} \quad \ldots.(24)$$

Effect of Reduction Ratios

The reduction ratio *Rr* is the ratio of the size of the new mill feed to that of the final product, or *F*/*P*. With scalped feed, *Fc*/*P* should be used. Rod mills are particularly sensitive to unfavourable reduction ratios, and if *F*/*P* is smaller than about 12 or larger than about 20 the kWh/ton (*W*) required for grinding increases. If *Rro* represents the optimum rod mill reduction ratio, its approximate value is found from

$$Rro = 8 + 5L/D \quad \ldots.(25)$$

When the actual reduction ratio *Rr* is much smaller or larger than *Rro*, the work input *W* from Equation (1) should be multiplied by the empirical adjustment factor A_2, where

$$A_2 = 1 + 2(Rr - Rro)^2/300 \quad \ldots.(26)$$

Since peripheral discharge rod mills have low reduction ratios, they normally require an increase in *W*.

Ball mills are less sensitive to changes in reduction ratio than rod mills. However, when *Rr* becomes less than about 3, particularly in the fine grinding of concentrates, *W* from Equation (1) should be multiplied by the empirical adjustment factor A_3, where

$$A_3 = \frac{20(Rr - 1.35) + 2.60}{20(Rr - 1.35)} \quad \ldots.(27)$$

Free Vertical Oscillation

A body in free vertical oscillation falls from its highest position under the influence of gravity and is stopped forcibly by an equal deceleration; it is then accelerated upward at the same rate and reaches the same highest position as before. It describes a simple harmonic motion over a vertical distance of *h* inches with *cpm* cycles per minute, where

$$\sqrt{h} = 295/cpm \quad \ldots.(28)$$

The critical frequency of vibrating bodies is calculated from Equation (28); as the *cpm* (or rpm) decreases below the critical, the tendency to maintain free vertical oscillation causes the amplitude *h* to increase.

The power necessary to maintain free vertical oscillation is directly proportional to the period of oscillation ($1/cpm$) and to $\sqrt{h}$. Where *Kvo* is the kilowatts necessary to maintain a ton mass in free vertical oscillation, then

$$Kvo = 328/cpm = 1.11\sqrt{h} \quad \ldots.(29)$$

The vertical component of the motion of a particle of no diameter against the lining of a ball mill at critical speed corresponds to free vertical oscillation with $h = 12D$, and *cpm* = rpm.

Effect of Oversize Feed

Feed particles which are too large for the grinding balls or rods to break are gradually worn down in the mill with a considerable loss of grinding efficiency. If the mill product

is coarse, the loss in mill capacity can be quite large; it decreases as the proportion of the total work consumed in fine grinding increases. The decrease in capacity caused by oversize grinding media is not as pronounced as that caused by oversize feed.

When Fo represents the maximum 80 per cent passing feed size in microns which does not appreciably decrease the grinding efficiency (is not oversize) with the ball or rod size calculated from Equation (12) or (13), and the work index is 13, Fo is about 4000 for ordinary ball mills and 30,000 for rod mills.

$$\text{For ball mills } Fo = 4000\sqrt{(13)/Wi} \quad \ldots.(30)$$

$$\text{For rod mills } Fo = 30{,}000\sqrt{(13)/Wi} \quad \ldots.(31)$$

The work input W for oversize feed ($F > Fo$) is calculated from

$$W = \left[\frac{10\ Wi}{\sqrt{P}} - \frac{10\ Wi}{\sqrt{F}}\right]\left[\frac{Rr + (Wi - 7)\ (F - Fo)/Fo}{Rr}\right] \quad \ldots.(32)$$

Grind Differential

The grind differential Gd evaluates the difference in the particle sizes of the concentrate and tailing when grinding for mineral unlocking and concentration by flotation or by gravity. An increased grind differential can be of major importance in such grinding circuits.

Where P is the 80 per cent passing size in microns of the feed to concentration, Cp is the 80 per cent passing size of the concentrate, and Cw is the per cent weight of the concentrate divided by the feed, the grind differential[11] is

$$Gd = \frac{P\ (150 - Cw) - 50\ Cp}{P\ (50 - Cw) + 50\ Cp} \quad \ldots.(33)$$

A typical copper flotation plant has a grind differential of 1.34. Any change in the grinding circuit which would increase the grind differential would result in relatively coarser grinding of the gangue, and should favourably affect costs, recovery and grade.[11]

When making two grinds to 80 per cent passing a given product size P, with the first grind differential Gd_1 larger than the second grind differential Gd_2, the relative mechanical efficiency of the first grind to the second is:

$$\text{Rel. Eff.} = \sqrt{1 + \left(\frac{Gd_1 - 1}{Gd_1 + 1}\right) - \left(\frac{Gd_2 - 1}{Gd_2 + 1}\right)} \quad \ldots.(34)$$

If the recession factor Rf is the number of standard $\sqrt{2}$ screen scale spaces between size P and size Cp, then

$$Rf = (\log P - \log Cp)/\log\sqrt{2} \quad \ldots.(35)$$

$$P = Cp\ (2)^{\frac{Rf}{2}} \quad \ldots.(36)$$

The grind differential Gd can be calculated from the recession factor Rf and the per cent weight of the concentrate Cw by substituting the value of P from Equation (36) into Equation (33).

The Schuhmann slope α of the heavier concentrate is commonly greater than that of the lighter tailings.

Classifier Performance

In closed-circuit reduction the efficiency and the separating size, cut point or parting size of the classifier or screen are important. The efficiency is commonly expressed as 100 minus the per cent of finished material or "unders" in the oversize returned to the mill or crusher, at a certain selected sieve size.

The parting size is defined as the size at which the per cent "unders" in the separator oversize equals the per cent "overs" in the separator undersize. The separator undersize per cent passing, and the separator oversize per cent cumulative retained on, are plotted as smooth curves on the same linear or logarithmic graph sheet. The point where the two lines cross is the parting size, and the per cent passing at the crossing point is the per cent efficiency of the separator.

Percentage Circulating Load

In closed-circuit reduction the per cent circulating load (100 Cl) is 100 times the ratio of the weight of separator oversize returning to the reduction machine to the weight of the new feed entering the circuit in the same time interval.

P = microns 80 per cent of separator undersize passes.
Fp = per cent of new feed passing size P.
Dp = per cent of machine discharge passing size P.
Rp = per cent of separator oversize passing size P.

When the new feed enters the reduction machine

$$Cl = (80 - Dp)/(Dp - Rp) \quad \ldots.(37)$$

When the new feed enters the separator

$$Cl = (80 - Fp)/(Dp - Rp) \quad \ldots.(38)$$

The quantities required in Equations (37) and (38) can be determined from log-log or exponential plots of complete size distribution analyses. However, the screen analyses available may not permit determination of these quantities, and Cl must be calculated from the old equations[14] based on the percentages passing 200 mesh or any other available fine screen.

If c represents the per cent of the classifier fine product passing 200 mesh, t is the per cent of the classifier coarse product passing the same size, and m is the per cent of the mill discharge passing the same size, then when the new feed enters the grinding mill

$$Cl = (c - m)/(m - t) \quad \ldots.(39)$$

When the new feed enters the classifier, and f_a represents the per cent of the new feed passing 200 mesh, then

$$Cl = (c - f_a)/(m - t) \quad \ldots.(40)$$

Any other suitable screen size may be substituted. However, the Cl values calculated from different screen sizes usually show a wide variation, and the mesh size at which the circulating load is calculated should be specified.

Per Cent new Classifier Feed to Closed-circuit Mill

When a rod mill in open circuit discharges to a classifier in closed circuit with a ball mill, the per cent of the rod mill discharge which enters the ball mill as scalped new feed equals

$$100 - \left[\begin{matrix}\%\text{ of rod mill discharge} \\ \text{passing parting size}\end{matrix}\right]\left[\frac{\%\text{ Eff.}}{100} + \frac{100 - \%\text{ Eff.}}{100\ Cl}\right] \quad \ldots.(41)$$

Closed-circuit Versus Open-circuit Ball Mill Grinding

The listed work index values apply to ball mills grinding wet in closed circuit. For dry grinding in closed circuit, the work input W should be multiplied by 1.30.

The conversion to open-circuit grinding, either wet or dry, is done by multiplying the closed-circuit work input W by an open-circuit multiplication factor. In this connection the circulating load Cl should be unity or greater.

This factor varies with the reference per cent passing, or the per cent passing at which the open- and closed-circuit grinding are compared. For instance, if the reference per cent passing is 95, the multiplication factor will be much larger than at 80 per cent passing. If it is required that 95 per cent of the product passes 200 mesh the change from closed circuit to open circuit will require a much greater increase in power than if it is required that 80 per cent pass 200 mesh, or any other specified mesh size.

Some approximate open-circuit multiplication factors for various reference percentages passing are listed below in Table IV. They follow an exponential function.

TABLE IV

Reference per cent passing	Open-circuit multiplication factor
50	1.035
60	1.05
70	1.10
80	1.20
90	1.40
92	1.46
95	1.57
98	1.70

Correction for Work Index Variations

When an ore has natural grain sizes, it sometimes happens that laboratory rod mill and ball mill grindability tests and impact crushing tests give different work index (Wi) values on the same sample at different product sizes. This complicates the calculation of the work input required (W) in kWh/ton from Equation (1), which is used with the desired capacity to find the required motor and mill size.

When this happens the various work index values are plotted vertically as ordinates on log-log paper against the 80 per cent passing sizes as abscissae, and the points are connected by straight lines which are extended horizontally to the edges of the paper. The 80 per cent passing sizes of grindability test products are found by dividing the screen openings P_1 in microns by log 20 (1.301), or by the values given following Equation (8) for fine ball mill tests. The 80 per cent passing size is 1.5 in. for the impact crushing tests.

The work index values at the designated 80 per cent passing product size P and feed size F are found from the plot and designated as Wi_p and Wi_f. Then the work input W is found from Equation (42) as given below:

$$W = \frac{10\ Wi_p}{\sqrt{P}} - \frac{10\ Wi_p}{\sqrt{F}} + \frac{10(Wi_f - Wi_p)}{1.5\sqrt{F}} \quad \ldots . (42)$$

Appendix

TABLE 1A

Symbol*	In Equation No. †	Description	Symbol*	In Equation No. †	Description
A	4	Exponential plot slope.	k_{100}	2, 3	Schuhmann microns 100 per cent passes.
A_1	—	Fine product adjustment factor.	L	16, 17	Length of mill interior in feet.
A_2	26	Rod mill Rr adjustment factor.	Li	3	Grind limit in microns.
A_3	27	Ball mill Rr adjustment factor.	m	39, 40	Per cent passing in mill discharge.
Bl	—	Diam. in inches of balls and rods fed.	Nc	18	Critical mill speed in rpm.
Bl	5	Blaine surface area in sq. cm/gram.	No	20	Optimum mill speed in rpm.
b	4	Exponential size distribution coefficient.	Oss	10	Open side crusher setting in inches.
C	6	Ft.-lb per inch, impact crushing strength.	P	—	Product size—microns 80 per cent passes.
Cl	9, 37, 38, 39, 40, 41	Per cent circulating load/100.	P_1	13, 14	Sieve opening in microns—A–C grindability.
Cp	33, 35, 36	Microns 80 per cent of concentrate passes.	Q	15	Feet from top of mill to charge.
Cr	—	Total crack length—cm/cc.	Qd	23	Feet from top of mill to lowest discharge point.
Cs	12, 13, 19	Fraction of mill critical speed.	ρ	3	Density.
Css	11	Close side crusher setting in inches.	Rf	35, 36	Recession factor between concentrate and feed.
Cw	33	Per cent weight of concentrate in feed.	Rp	37, 38	Per cent of oversize passing size P.
c	39, 40	Per cent passing in classifier fine product.	Rr	4, 5	Reduction ratio = F/P.
cpm	28, 29	Cycles per minute in free vertical oscillation.	Rro	25	Optimum rod mill reduction ratio.
D	19, 21–25	Inside mill diameter in feet.	Sc	3	Surface area in sq. cm/gram.
Dp	27, 38	Per cent of discharge passing size P.	Sg	6	Specific gravity of ore.
d	1	Microns 80 per cent passes.	Ss	24	Ball slump subtraction quantity.
Ecc	11	Eccentric throw of crusher in inches.	Sw	5	Sq cm per gram, Wagner surface.
Er	4b	Exponential plot exposure ratio.	Tb	16	Tons of balls in mill.
F	1, 2, 3, 4, 19, 32	Feed size—microns 80 per cent passes.	Tr	17	Tons of rods in mill.
Fc	—	Equivalent size of scalped feed.	t	39, 40	Per cent passing in classifier coarse product.
Fo	30, 31, 32	Maximum efficient feed size in microns.	Vp	15	Fraction mill volume occupied.
Fp	38	Per cent of new feed passing size P.	Vpd	23	Fraction of mill volume below discharge level.
f	5	Diameter of feed particle in microns.	W	1, 2, 3,	Work input in kWh per short ton.
fa	40	Per cent passing in mill new feed.	Wi	1, 6–13	Work index: kWh/ton to 80 per cent—100 microns.
Gd	33, 34	Grind differential.	Wt	1, 10	Work total: kWh/ton to product size.
Gbp	8	Ball mill grindability A–C, net grams/revolution.	w	—	kWh/Wi
Grp	7	Rod mill grindability A–C, net grams/revolution.	X	4	Exponential plot abscissa.
Hd	9	Hardgrove grindability.	Y	4	Per cent cumulative retained on any size.
h	28	Inches of free vertical oscillation.	α	2, 3	Slope of size distribution line.
K	—	Grinding media size constant.	Wi_p	42	Work Index from plot at product size P.
Kvo	29	Kilowatts per ton in free vertical oscillation.	Wi_f	42	Work Index from plot at feed size F.
Kwb	22	Kilowatts per ton of balls.			
Kwr	21	Kilowatts per ton of rods.			

*In this paper three classes of symbol are used: lower case single letters, upper case single letters and compound symbols consisting of an upper case letter followed by one or more lower case letters. They are distinguished by the sequence rule; lower case single letters are written first, followed by upper case single letters, and in every term the compound symbols are written last.

† Equations (2), (18), (39) and (40) were not derived by the author.

TABLE IIA—Abrasion Index Test Results

Abrasion index Ai is the fraction of a gram weight lost by the standard steel paddle in 1 hr of beating 1600 grams of ½ in. × ½ in. particles. The product averages 80 per cent passing 13,250 microns

Material	No. Tested	P Microns	Wi	Average Ai	Material	No. Tested	P Microns	Wi	Average Ai
Alnico	1			0.3850	Limestone	19	13,000	12.1	0.0256
Alumina	6	15,500		0.6447	Magnesite	3	14,400	16.8	0.0750
Asbestos cement pipe	1	13,330		0.0073	Magnetite	2		10.2	0.2517
Cement clinker	2	12,100	10.9	0.0409	Manganese ore	1		17.2	0.1133
Cement raw material	4		10.5	0.0372	Nickel ore	2		11.9	0.0215
Chrome ore	1	10,200	9.6	0.1200	Perlite	2			0.0452
Coke	1		20.7	0.3095	Pumice	1		11.9	0.1187
Copper ore	12	12,900	11.2	0.0950	Quartz	7		12.8	0.1831
Coral rock	1			0.0061	Quartzite	3		12.2	0.6905
Diorite	1		19.4	0.2303	Rare earths	1			0.0288
Dolomite	5		11.3	0.0160	Rhyolite	2	13,200		0.4993
Gneiss	1		20.1	0.5360	Schist-biotite	1		23.5	0.1116
Gold ore	2		14.8	0.2000	Shale	2	11,200	11.2	0.0060
Granite	11	15,200	14.4	0.3937	Slag	1		15.8	0.0179
Gravel	2		19.0	0.3051	Slate	1		13.8	0.1423
Hematite	3		8.6	0.0952	Sulphur	1		11.5	0.0001
Iron ore (misc.)	4		5.4	0.0770	Taconite	7		16.2	0.6837
Lead zinc ore	3		8.3	0.1520	Trap Rock	11	14,900	19.9	0.3860
					(Total)	125(Av.)	13,250	13.8	0.228

TABLE IIIA—Average Work Indexes by Types of Materials
Caution should be used in applying the average work index values listed here to specific installations, since the individual variations between materials in any classification may be quite large.

Material	No. of Tests	Average Specific Gravity *Sg*	Average Work Index *Wi*
All materials tested	2088	—	13.81
Andesite	6	2.84	22.13
Barite	11	4.28	6.24
Basalt	10	2.89	20.41
Bauxite	11	2.38	9.45
Cement clinker	60	3.09	13.49
Cement raw material	87	2.67	10.57
Chrome ore	4	4.06	9.60
Clay	9	2.23	7.10
Clay, calcined	7	2.32	1.43
Coal	10	1.63	11.37
Coke	12	1.51	20.70
Coke, fluid petroleum	2	1.63	38.60
Coke, petroleum	2	1.78	73.80
Copper ore	308	3.02	13.13
Coral	5	2.70	10.16
Diorite	6	2.78	19.40
Dolomite	18	2.82	11.31
Emery	4	3.48	58.18
Feldspar	8	2.59	11.67
Ferro-chrome	18	6.75	8.87
Ferro-manganese	10	5.91	7.77
Ferro-silicon	15	4.91	12.83
Flint	5	2.65	26.16
Fluorspar	8	2.98	9.76
Gabbro	4	2.83	18.45
Galena	7	5.39	10.19
Garnet	3	3.30	12.37
Glass	5	2.58	3.08
Gneiss	3	2.71	20.13
Gold ore	209	2.86	14.83
Granite	74	2.68	14.39
Graphite	6	1.75	45.03
Gravel	42	2.70	25.17
Gypsum rock	5	2.69	8.16
Ilmenite	7	4.27	13.11
Iron ore	8	3.96	15.44
Hematite	79	3.76	12.68
Hematite—specular	74	3.29	15.40
Oolitic	6	3.32	11.33
Limanite	2	2.53	8.45
Magnetite	83	3.88	10.21
Taconite	66	3.52	14.87
Kyanite	4	3.23	18.87
Lead ore	22	3.44	11.40
Lead-zinc ore	27	3.37	11.35
Limestone	119	2.69	11.61
Limestone for cement	62	2.68	10.18
Manganese ore	15	3.74	12.46
Magnesite, dead burned	1	5.22	16.80
Mica	2	2.89	134.50
Molybdenum	6	2.70	12.97
Nickel ore	11	3.32	11.88
Oil shale	9	1.76	18.10
Phosphate fertilizer	3	2.65	13.03
Phosphate rock	27	2.66	10.13
Potash ore	8	2.37	8.88
Potash salt	3	2.18	8.23
Pumice	4	1.96	11.93
Pyrite ore	4	3.48	8.90
Pyrrhotite ore	3	4.04	9.57
Quartzite	16	2.71	12.18
Quartz	17	2.64	12.77
Rutile ore	5	2.84	12.12
Sandstone	8	2.68	11.53
Shale	13	2.58	16.40
Silica	7	2.71	13.53
Silica sand	17	2.65	16.46
Silicon carbide	7	2.73	26.17
Silver ore	6	2.72	17.30
Sinter	9	3.00	8.77
Slag	12	2.93	15.76
Slag, iron blast furnace	6	2.39	12.16
Slate	5	2.48	13.83
Sodium silicate	3	2.10	13.00
Spodumene ore	7	2.75	13.70
Syenite	3	2.73	14.90
Tile	3	2.59	15.53
Tin ore	9	3.94	10.81
Titanium ore	16	4.23	11.88
Trap rock	49	2.86	21.10
Uranium ore	20	2.70	17.93
Zinc ore	10	3.68	12.42

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Research in Pelleting

THE Research and Development Division of Head Wrightson has built two pelletizing drums for experimental work. Their research in this field is done in collaboration with Head Wrightson Stockton Ltd., who manufacture and market this equipment. A large drum and a small one have been constructed, and details are given below.

The slope and rpm of the larger drum are both variable, and as it is in fact of the same-size order as many "industrial" drums, it can be expected to be a most useful piece of equipment. It is roller mounted and if necessary and more convenient, could be taken to a site to study a client's problem on the spot.

The smaller drum is for bench work used to appraise the relevant properties of different powders and binders; and also to produce small batches of pellets for subsequent experimental work.

In the photograph, for example, Norwegian magnetite concentrates are being pelletized; enquiries have been received on the treatment of fume from gas cleaners following oxygen steelmaking furnaces, and work has started on this problem.

Small pelletizing drum installed at the laboratories of Head Wrightson's Research and Development Division.

In general these drums are used to assess the possibility of making adequate pellets from any material and test work is directed to determining the appropriate: (a) degree of wetness; (b) pelletizing aid—or binder; (c) retention time.

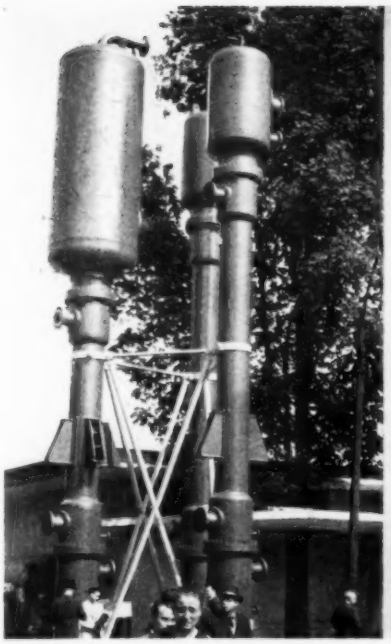


Fig. 1. Evaporating equipment shown by a company who were much in evidence at the Exhibition—Ruhrstahl.

Fig. 2. Tape-wound pressure vessel for ammonia synthesis shown by Phoenix-Rheinrohr.

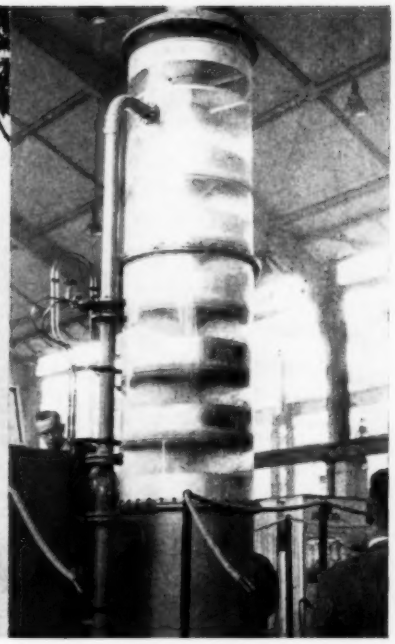


Fig. 3. A demonstration of a column fitted with Kittel trays on the stand of J. Stahl.

ACHEMA 1961

THE recently concluded Achema Exhibition, quite one of the largest of its kind in the world and an important event accompanying the European Convention of Chemical Engineering, proved to be a great success, whether judged from its attendance of 134,000, the technical level of the exhibits, the number of exhibitors (in excess of 1300) or of the high proportion of novelty among the equipment presented.

This was particularly noticeable in the fields of mixing, mechanical separation and particle size reduction and, in addition, there was a fair sprinkling of novelty in equipment for heat and mass transfer operations. Apart from process control equipment, which was much in evidence, there was, as is usual in displays of processing hardware, a great deal of ancillary equipment such as pumps, valves and the like. There were also a number of interesting designs of plant which, although established on the Continent, were unfamiliar to British eyes.

Another feature of the Exhibition was the variety of materials of construction in which glass and glass-lined equipment were especially prominent along with plastic constructions which ranged from pipework fittings and pumps to cooling towers and processing vessels; finally, not the least noteworthy, were the models of complete plants and manufacturing units covering a broad area of the processing industry.

Distillation

In terms of novelty this section was perhaps not strongly represented although many existing designs such as Ballast trays shown by Gütehöffnungshütte Sterkrade A.G., Kittel trays, various packed glass columns shown by Q.V.F., Jenaer Glaswerke Schott, and others were shown. On view was the Kloss high vacuum column, recently described in this journal (the contact units consist of helical springs over which the liquid is caused to flow filmwise), which allows a vapour velocity up the column of 50 m/sec or greater and is suitable for vacua in the range 40-0.1 mm Hg. Distillationstechnik Stage K.G. displayed two types of bubble cap plate in glass for small scale work, one being termed a baffle plate, a special construction in the form of an inverted bubble cap; the second is an improved bubble cap, both types having an efficiency independent of throughput over a wide range. Vapour baffle trays have a further advantage, low liquid hold-up.

Other devices shown by the Stage concern included trickle column packing made from honeycombs of perforated or expanded metal. Figures presented by the company show exceptionally low pressure loss per theoretical tray. For example, for a vapour velocity of 80 m/sec. the pressure loss for 40 × 40 mm mesh packing is of the order of 6 mm wg and the HETP value, based on a mixture of phenol and orthocresol, the distillation being carried out at 2 mm Hg abs, is 1.1 m for the above vapour velocity.

Of other packings a wide variety was shown by Normschliff Glasgeräte and Dr. Schliebs & Co.; the former showed gauze rings with and without bridge, pitched coils, McMahon saddles, all in stainless steel or bronze, and Wilson glass helices; Schliebs showed packings in acid resistant refractory materials including carbon, glass, quartz glass and various plastics; these included super saddles and interlock packings. Also noteworthy was a Kuhn column shown by Sulzer and described recently in this journal.

Low Pressure Nitric Acid Tower

A new design of nitric acid tower, system Lutz, was demonstrated by F. J. Gatty, of Frankfurt. One feature is the use of the column inner surface as the heat transfer surface through which the heat of the oxidation reaction is removed, jacket water-cooling being provided at the outer surface of the column. Another is the special design of tray which has a well at its centre containing a number of bubble caps (Fig. 15). The well is enclosed so that the vapours, which have passed through the caps, entraining some liquid, are forced to pass through radial tubes which direct them at high speed tangentially against the column wall. As a result, high heat transfer rates are obtained and the gases are rapidly cooled before passing to the well of the tray above. The liquid is transferred to the outer section of the tray from the tray immediately above, and it is in this space that most of the chemical reaction takes place. In the demonstration of this tray considerable movement of the liquid upon the flat outer section was observed, lending weight to the claim of complete absence of dead spots.

The column is capable of producing acid of 60 per cent strength and its use makes unnecessary the installation of blowers and expanders required by pressure absorption plants. Circulating

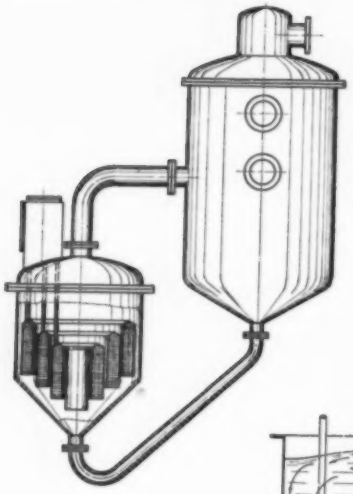


Fig. 4. An evaporator scheme using an induction heated boiler, shown by Julius Montz Hilden. Temperatures up to 550° C are possible with this system.

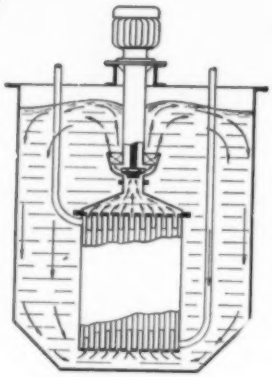


Fig. 5. A novel combination shown by the Swedish Stamo company—a turbine impeller with stator combined with shell-and-tube heat exchanger.

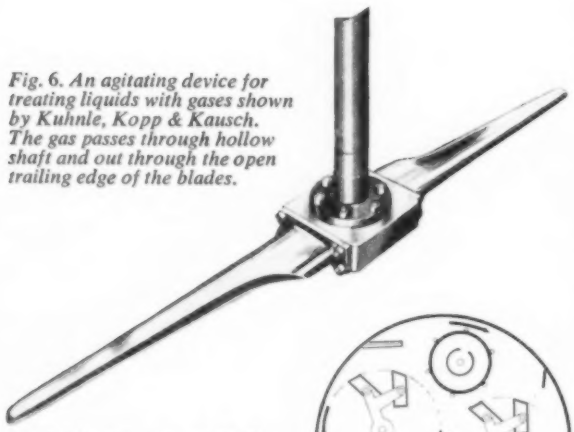


Fig. 6. An agitating device for treating liquids with gases shown by Kuhnle, Kopp & Kausch. The gas passes through hollow shaft and out through the open trailing edge of the blades.

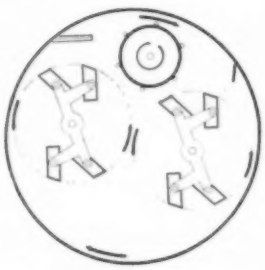


Fig. 7. The operating principle of a machine shown by Eirich for heavy duty mixing; four rollers are employed per rotor, the pan rotates, and additional agitation is provided by the non-planetary element.

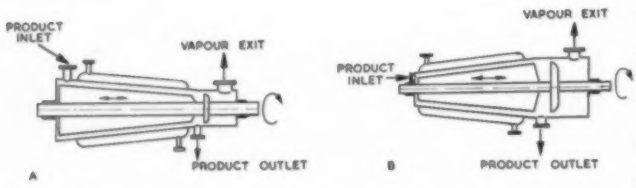


Fig. 8. A thin film reactor (Kontro design) shown by Samesreuther. The rotor is adjustable axially.

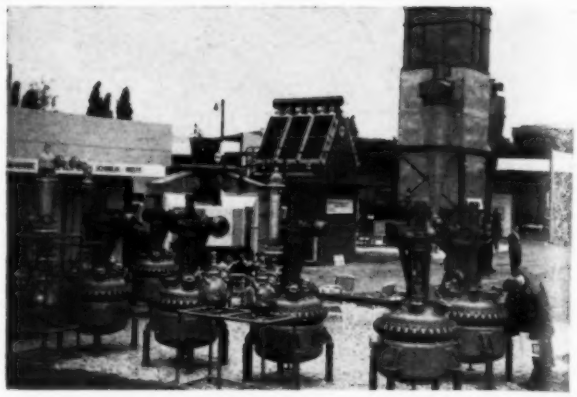


Fig. 9. A group of glass-lined closed reaction vessels, some equipped with glass reflux condensers, shown by Schwelmer Eisenwerk.

pumps, usually something of a nuisance, and external heat exchangers are also not required. The claim of lower first cost for this tower, despite its larger bulk, as compared with the totality of equipment required by high pressure absorption seems justified. A point, too, is that the wall thickness of the tower need not be great in view of the low operating pressure dictated by the maximum pressure to force the gases through the column.

Tray Sealing Devices

Two novel methods of sealing trays against column walls were on view, one shown by Peter Dinckels and the other by Julius Montz Hilden. The latter is used for columns of small diameters and consists of a helical spring made from rectangular or circular wire which is housed in a state of compression in a casing attached to the tray. When fitted into the column the spring presses against the column wall and provides a flexible seal, which is completely tight to liquid but which permits a certain amount of vapour leakage at the small gaps in the springs (Fig. 21).

The Dinckels device makes use of a wide "U" shaped piece of material, metallic or plastic, which is attached loosely to a tray through a slight indentation at its narrow edge. Threaded through the arms of the "U" are a number of curved bolts with nuts which, when tightened, force the edges of the "U" against the wall of the vessel, making at the same time an edge seal against the side of the column tray. The edge contact at tray and column wall, the pressure of which is adjustable by means of nuts and bolts, in combination with the liquid submergence, provides the seal. This device is obtainable for columns up to 1.2 m in diameter.

Also shown by Julius Montz Hilden were the Streuber trayplates using the box construction principle. This is a form of bubble tray using "U" troughs which are laid over rectangular openings provided by the insertion of segmental plates around the periphery of a column, the troughs and hoods being anchored by hook bolts; the method of construction provides a completely flat tray and precise adjustment of hoods to depth of liquid seal (available from Coppee-Montz in Britain).

Tape Wound Pressure Vessel

Apart from the example of this form of construction shown by Phoenix-Rheinrohr (Fig. 2) another vessel of the same type was shown by Nikex, the Hungarian Export Organization. Nikex offer vessels of this type in which the inner diameters range from 480 to 1200 mm in lengths up to 18 m although designs outside these dimensions can be made to special order. The stated upper operating temperatures and pressures are 350°C and 350 atm respectively. The vessels can be supplied with high pressure detachable closures or with spherical ends welded to either one or both ends.

A reactor for ammonia synthesis made according to the multilayer method of A. O. Smith was also presented by Ruhrstahl, the dimensions being 850 mm id 1056 mm od and the length 14.2 m.

Heat Transfer Equipment

Equipment for heat transfer, or for processes in which heat transfer plays an important role, included conventional shell-and-tube equipment, film evaporators and reactors, and cooling towers. In the field of film evaporation a number of designs were to be seen, including one by Samesreuther & Co. con-

Fig. 10. Considerable interest was shown in the varied equipment shown by Carl Canzler. In the foreground, a Rotafilm wiped-film evaporator.

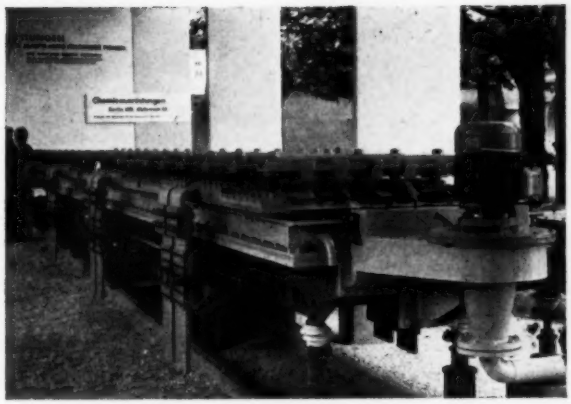


Fig. 11. A group of cells for the electrolysis of sodium chloride solutions for the manufacture of 50 per cent caustic soda. (Deutsche Innen und Aussenhandel.)

structed according to the Kontro system whereby the evaporator is preferably placed horizontally (Fig. 8). Its principal advantage is the possibility of adjusting the position of the conical rotor along its axis during operation, so that the clearance between rotor and the jacketed vessel wall can be varied at will, a feature which is distinctly useful when materials of high viscosity have to be treated. Usually, in addition, the coupling of an infinitely variable speed control to the rotor is advantageous because it allows turbulence to be avoided.

This design has a wide field of application apart from straightforward evaporation or heating or cooling and its makers make a point of its suitability for chemical reactions.

Six models are made in either vertical or horizontal versions. For the former, heating surfaces are in the range 0.10-6.50 m^2, for the latter, 0.10-13.0 m^2; installed hp ranges are 1-25, and 1-50 respectively and depend upon the viscosity of the material being treated; maximum evaporative capacities, based upon steam at 1 atm and water evaporating at 60 mm Hg, are 1200 and 2200 kg/h.

Another film evaporator, applicable to heat sensitive liquids, was shown by Separator AB (Stockholm). This equipment (the Centri-Therm) was described recently in the Press upon its introduction into this country. It will be recalled that it is a centrifugal evaporator in which the problem of prolonged heating is eliminated by evaporating the liquid under vacuum and centrifugal force (as high as 200 g) so that many concentrations can be completed in little more than a second, and less in some instances.

Characteristic of its performance are the high heat transfer rates to which the rapid removal of condensate from the steam heated upper surface, the very small film thicknesses and high turbulence contribute. The basis of the design is a stack of rotating conical elements supported upon a hollow shaft, each one being hollow and together with the walls of the containing vessel, forming steam jackets, the steam being supplied through the hollow shaft.

Among the shell and tube equipment was noted a more or less conventional multi-tubular exchanger with graphite shell and tubes containing, within the tubes, elastic inner tubes for reducing the cross-sectional area for the tube side fluid. This is particularly useful where a small quantity only of tube fluid is available or has to be processed. The same company, Sigri-Kohlefabrikate GmbH, also had on view a new combustion furnace for manufacturing HCl which had been developed in collaboration with BASF. Material of construction is impregnated graphite (Diabon)and the equipment is virtually explosion-proof. The model with a 610 mm internal width of furnace has an output of around 25 t/d of HCl. Other designs of interest shown by this company included an air-cooled extended surface plate heat exchanger constructed also from impregnated graphite (Diabon).

Induction Heated Equipment

For the attainment of processing temperatures up to 550°C, induction heating, although not widely practised in Britain for processes, is growing in popularity. A design of this kind employing concentric immersion units was among the equipment exhibited by Julius Montz Hilden (Fig. 4). Advantages, which in British conditions may be outweighed by the cost of electrical energy, include versatility, speedy putting into operation, safety —since no explosion hazard accompanies this form of heating— close and very rapid control of temperature, high heat transfer rates per unit volume of heater, and high efficiency.

The induction coils are arranged concentrically and staggered vertically, an arrangement conducive to good liquid circulation. The system employed by Montz was developed by Junkers (Lammersdorf) and it consists of generating an alternating magnetic field by means of coils connected to a 50 cycle supply of normal voltage. The energy of this field is transformed into heat on an iron casing which transfers its heat to the processed material by radiation, conduction and convection. The casing can be plated for the treatment of corrosive media.

"Water Bed" Conveyor Cooler

A solution to the problem of continuous and rapid cooling or crystallizing of molten salts or solutions, is to feed the molten material or solution on to a polished metal band conveyor equipped with a water bed in contact with the underside of the upper run of the conveyor band; the discharge of the solidified salt takes place where the band passes over the driven roller. Such a device was displayed by Sandvik Steel Works, and the following figures give some idea of the performance to be expected from this type of cooler; sulphur fed at 148°C can be cooled to 50°C in six minutes; sodium metasilicate from 70°C to 30°C in thirteen minutes, and sodium hexametaphosphate from 600°C to 220°C in two minutes. In the case of one sulphur application, 6 to 7 tons/h are handled upon a 40 in. wide stainless steel band, with a cooled bed of 200 ft which is traversed in 4 minutes. The sulphur is unloaded in ¼ in. thick layers.

Rotary Cooler

Cooling of solid materials can be effectively carried out by a little known rotary cooler manufactured by Büttner and demonstrated by this company at the exhibition. The hot material such as is discharged from a kiln is fed into the cooler by a screw coupled to a variable speed drive. The water-cooled chamber is divided into sector-like compartments in which the solids are cooled. During rotation the cooling drum passes through a water trough, and the drained off water is removed by scoops, a system which provides indirect cooling with the water flowing virtually filmwise over the exterior of the cooling surface. The cooled material is discharged by a screw conveyor to bags or containers. Capacities are above 20 tons/h, and maximum cooling surface in a single unit is in excess of 100 m^2; advantages of the cooler, which is well proven through a number of applications (e.g. cooling of pyrites waste), are avoidance of dusting so that dust collecting equipment is unnecessary, and small space occupied.

Wiped-Film Evaporator

A wiped-film evaporator, based upon the Smith system, was exemplified by a number of the Carl Canzler exhibits and known as the Rotafilm. In this apparatus the evaporation tube is externally heated and the vertical wiper system consists of a rotating drum fitted with axial "U" shaped channels. In these are inserted the loosely-fitting wiper elements which have diagonal notches cut on their contact surfaces; centrifugal force presses the blades against the vessel wall. The field for this design is the evaporating of heat sensitive liquids; by overhanging the rotor it is possible to place the condenser in the centre of the vessel close to the evaporating surface, a measure which permits short path and molecular distillations.

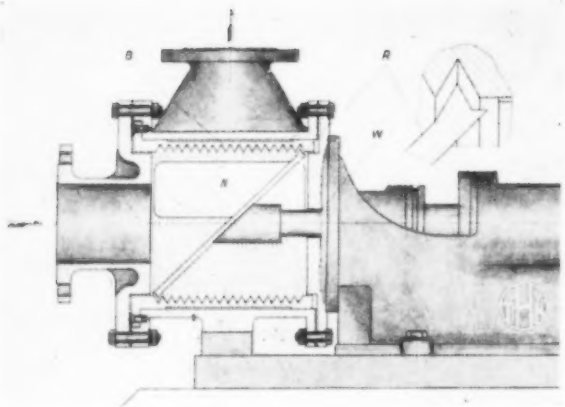


Fig. 12. An inclined-rotor pump with some of the characteristics of a centrifugal pump and capable of size reduction (Theodor Hoelscher).

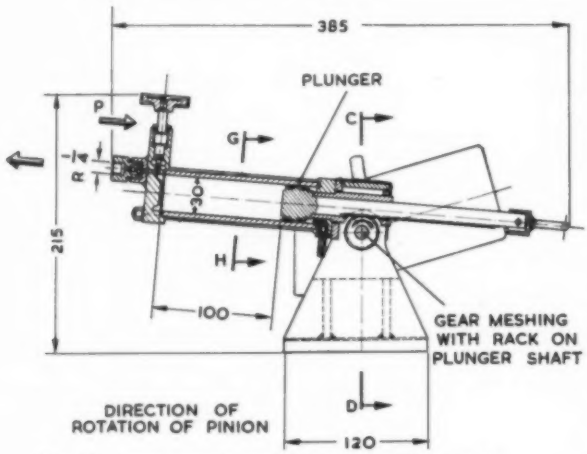
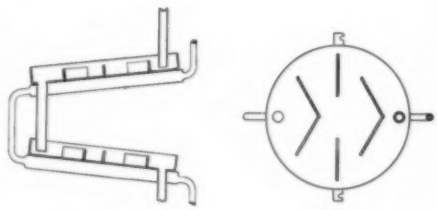


Fig. 13. A new metering pump from Lewa (Stuttgart). The piston is driven forward slowly to deliver the metered fluid in quantities as small as 1 cc/h.

Fig. 14. A cascade evaporator shown by Ruhrstahl, a design offered in most of the weldable corrosion resisting materials of construction.



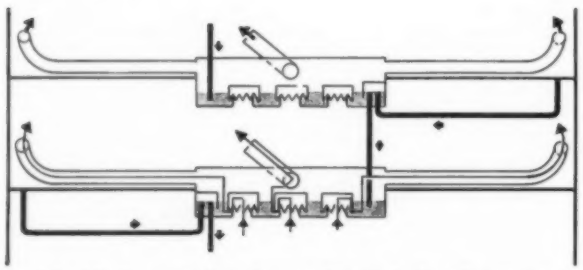


Fig. 15. A new design of tower for producing 60 per cent nitric acid. The design allows low pressure operation and uses the column wall for the surface through which heat of reaction is removed.

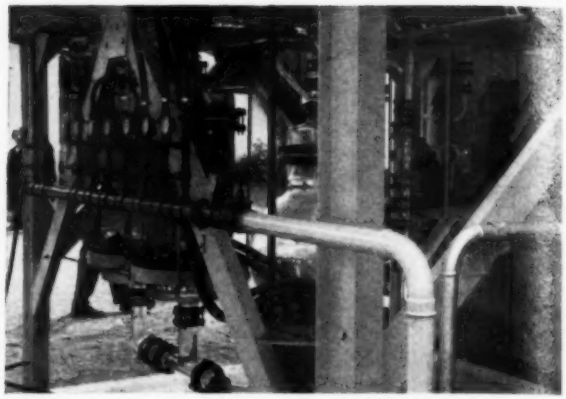


Fig. 16. A view beneath an all-glass distillation column shown by Jenaer Glaswerke Schott. To right can be seen a small glass metering pump for feeding liquor to the column.

The Rotafilm is offered in sizes from 50-900 mm. in diameter, heating surfaces ranging from 0·0.35 to 6 m² with condenser surfaces of 0.016-9 m².

Rosenblad heat exchangers, one of 1.5 m² constructed from Titanium for sulphuric acid, and a Cr-Ni alloy exchanger for gas-gas service at elevated pressures which used a lamellar form of construction wherein the plates bore closely-pitched indentations some ¼ in. deep, with a total surface of 325 m², were other noteworthy exhibits on the Canzler stand in the realm of heat transfer devices.

High Pressure Thin Film Evaporator

A notable design in thin film apparatus was represented by the thin film reactor shown by Techemos (D. E. Kramer, West Berlin). This is suitable for temperatures up to 300°C and pressures up to 350 atm. The agitator rotates at 5000 rpm, and shaft sealing is eliminated through the use of a magnetic coupling. The agitator can be supplied in two forms, one a helix mounted upon a hollow cylinder with staggered vertical blades fitted between the pitch of the helix, and a wobbler type consisting of a number of elements fitted at an inclination to the shaft (further information about this design will be published later in this journal).

Combined Heat Exchanger-Mixer

Among turbine type mixers was a high speed direct-coupled machine made by Stamo, which consists of a closed impeller rotating inside a stator attached to a vertical tube enclosing the impeller shaft. This stator shrouds the periphery of the impeller and the clearance between the lower edges of the stator and impeller, whose eye faces downwards, is small; the stator increases in cross section above the impeller where a number of radial blades bridge the space between stator wall and the hollow tube. The effect of this construction is to obtain rapid and intensive liquid phase mixing by vertical currents set up in the vessel, rotation of the main body of liquid being completely prevented.

Stamo showed an interesting application of this device—its attachment to a vertical tube-and-shell exchanger fitted within a processing vessel (Fig. 5); the vessel contents are withdrawn through the tubes vertically to the eye of the impeller and discharged through the stator entirely without swirl. According to some tests conducted upon an apparatus of this type by PROF. A. RASMUSSON of the Institution of Chemical Apparatus Technology, Stockholm, overall heat transfer coefficients of the order of 2000 k cal/m² n °C are attainable, lower figures being achieved when the shell side fluid is hot water. The velocity through the tubes is in the region of 0.5 m/sec and it should be borne in mind that this is a rather short tube exchanger so that the tube side coefficients are bound to be high.

Air-cooled Equipment

A number of other types of heat exchange equipment are worth noting. For example, Escher Wyss displayed an induced draught water-cooling tower, with shallow compact packing, rotating water distributor and a polyester glass reinforced casing; made in ten sizes nominal capacities, based upon a wet bulb temperature of 18°C, for cooling from 31°C to 26°C, are from 20,000 to 1,260,000 k cal/h. Various applications of air-

Fig. 17. A view of the Schilde hot-water heated rotary drum drier designed for heat sensitive materials.

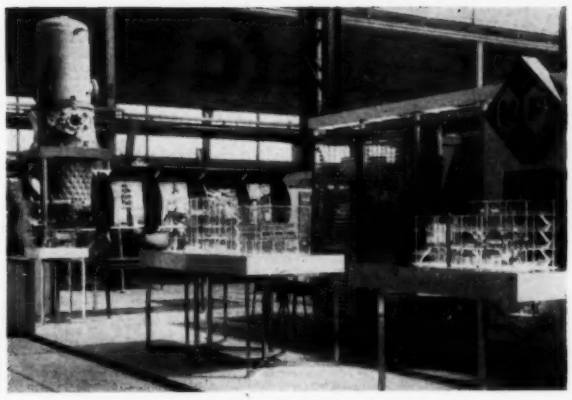


Fig. 18. Scene on the Karl Fischer stand, a company offering a number of complete process plants.

cooled equipment were the basis of GEA Luftkühlergesellschaft's exposition, an example being a condenser for such vapours as methanol, the economics of this application, according to figures given by the company, being much more attractive than those of water-cooled condensers.

The special form of lamellar exchanger made according to the system Ramens is now made with a cylindrical shell in addition to the rectangular sectioned casing, so that the advantages of this form of heat transfer surface are combined with the constructional advantages of the tube and shell system. Finally, CEMAT (Quai D'Orsay, Paris) introduced a compact type of exchanger which is virtually a stack of layers of corrugated sheets fixed between flat plates. This equipment made under licence with the U.S. Trane company has many applications in the cryogenic field and is available in a choice of four surface configurations with the corrugations, straight, serrated, herring-bone-shaped, or perforated. Some 1500 m^2 of surface can be accommodated with 1 m^3.

Drying Machinery: Drum Driers

A feature of a rotary drum drier shown by the firm of Schilde was the system of hot water heated hollow flights arranged somewhat in the form of a horizontal honeycomb within the drum. The flights are connected to a hot water jacket attached to the exterior of the drum, and are disposed so that retention of the material upon them is impossible. Heat transfer rates are high and the method of connecting the flights to the jacket makes it possible to apply heat in zones as desired. At the stand of this company (Fig. 17), there was usually evidence of plentiful interest in this design which is particularly suitable for materials which are sensitive to heat and which have low free-falling velocities.

A design produced by Erich Kiefer makes use of two perforated drums, each 1.5 m in diameter and working width, placed one above the other. The material to be dried is fed upon a belt at the front of the drier, and as the belt enters the machine, a second belt covers the material and both belts pass together over the perforated drums to the outlet of the drier, where the belts separate. The upper belt returns to the drums and the belt carrying the solids passes beneath them. The material discharges at the point where the belt reverses and is fed to a bunker from which it can be withdrawn pneumatically or filled into sacks. Advantages are dustless operation, effective drying and low space requirement.

Vibrator-Conveyor Drier

Another commendably simple design of drier or cooler was among the Wedag exhibits. It consists of a long vibratory conveyor made up of transverse metal strips mounted edgewise and with 1 mm. (approx.) spacing between adjacent strips. For drying, warm air is passed from the underside of this conveyor section through the vibrating mass of solid particles and is discharged through a vent, the entire drying section being enclosed. This compact design (made under licence from the U.S. concern Jeffrey) relies upon a mechanical vibration system and requires little power; the demonstration machine was equipped with a 1 kw motor.

Other drying units worthy of mention here are the Wiegand-Atlas freeze drying plant based upon steam jet ejectors made by this company.

Fluidizing Driers

Not unexpectedly there were a number of designs in this field which made use of the principle of fluidization. Thus the firm of Samesreuther showed in operation a discontinuous drier in which the moist material is fed on to a heated cone into which intermittent blasts of hot air are introduced from below. The demonstrated result was the imparting of a jetting and turning-over motion to the particles which produces extremely rapid drying of material with particles in the range 10 microns to 4 mm and with wide variations in particle size distribution. This type of drier does not reduce the material under treatment by attrition, and variation in particle sizes does not affect its efficiency adversely.

A continuous drier also relying upon fluidization was one of the principle exhibits of Keller of Leverkusen, and it is capable of handling pasty materials as well as such diverse materials as chips, fibres and fine powders. A feature of the design is that by multi-staging it is possible to discharge material separately according to its state of subdivision. Heat can be supplied by hot air or flue gases.

A quite different type of drier was demonstrated in model form by Maschinenfabrik Hartmann A.G. as part of a unit for the conveyance, cooling and drying of rubber pellets. The conveying part of the unit is part pneumatic and part mechanical. Under actual working conditions the pellets, about 1 cm^3 in

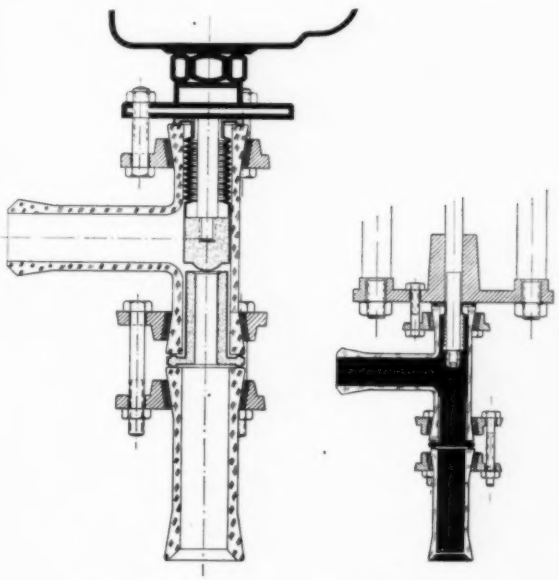


Fig. 19. Left a solenoid-operated glass valve with fluon bellows seal and to the right a pneumatically-operated control valve (tapered plug and seating omitted). Q.V.F. Glastechnik GmbH.

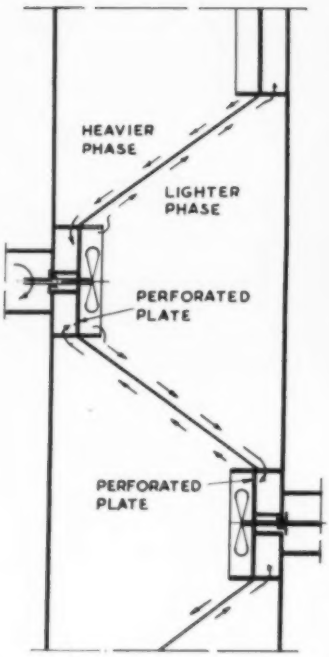


Fig. 20. An extraction column with propeller agitators shown by Peter Dinckels & Son.

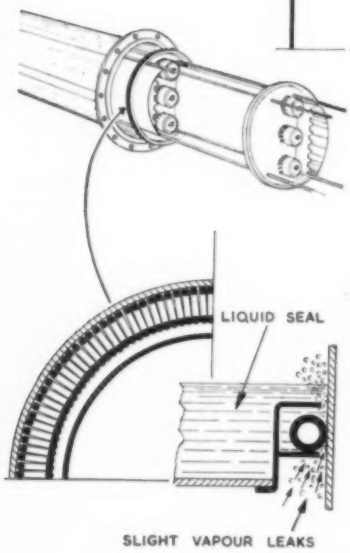


Fig. 21. A helical spring is the basis of this method of sealing distillation column plates against the column wall (Julius Montz Hilden).

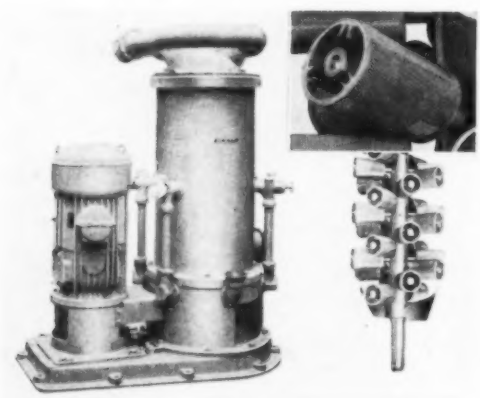


Fig. 22. A new type of grinding machine for ultra-fine particles, the Micromolitor.

Fig. 23. A wide range of mixing equipment machinery was shown by the British firm Stockdale Engineering Ltd.

size, have a temperature of about 170°C when they arrive: they are sprayed with coolant and then pass through the drier. The exit temperature at the screw feeding into the pneumatic suction system is about 40°C. The conveying unit is completely enclosed and arranged on three levels, one above the other, and it is ventilated by induced draught fans. The double strand chain, used as traction element, is fitted with perforated bearing plates which, in combination with guide vanes, provide a good drying effect. The speed of feeding can be adjusted independently for each stage by means of speed transmission, and thus the height of layers can be adjusted.

Jet Extractor

Another unusual device performs the task of separating a single solid from a mixture of solids with a liquid in such a manner that fresh water or process fluid is added to enhance the separation and at the same time to prevent the liquid from exerting a chemical effect upon the solid being separated.

The Starcosa-Jet extractor, as the apparatus is called, consists of a rotating cylindrical drum within which revolves a system of nozzles for introducing the treating liquid. The solids are fed to the inside of the drum and are met by jets of liquid issuing from the rotating nozzles in such a manner that the liquid tends to retard the movement of the solids towards the discharge end of the drum. This action causes the solids to be aerated and thoroughly washed, and the particles smaller in size than the mesh aperture pass through with the liquid, whereas the larger material is discarded at the discharge end of the drum.

For liquid-liquid extractions Peter Dinckels demonstrated the column shown here in diagram (Fig. 20), and further details are awaited of the performance of this interesting piece of hardware.

Mixers: Gas-Liquid

Several examples of machinery of this kind were on view, at least two making use of hollow shafts through which the gases to be dispersed are fed, and various arrangements of hollow impellers. A typical example was provided by Escher Wyss with a high speed rotating element consisting of a number of small "L" shaped blades mounted in five or more layers in a single impeller. At the knuckle of each "L" is fitted a fine jet through which the gas is discharged into the liquid. There may be, therefore, as many as 4-500 such jets for a single agitator. This apparatus is capable of giving a concentration of oxygen in water of ninety-nine per cent of the saturation value within ten to twenty minutes. The relevant figures given by the company are volume of 50 m^3 water treated with 110 Nm^3 of air per hour in one case and with double this amount of air in the other. The shorter time is achieved with the higher air rate. One noteworthy advantage of this apparatus, which has obvious applications in the fermentation industry. is that a vessel fitted with it can be sterilized without the necessity for further additional equipment.

Another device which also makes use of a hollow shaft was shown by Kuhnle, Kopp & Kausch but this is virtually the only similarity since the blading is quite different (Fig. 6). It consists of two aerofoil section blades with cutaways in the trailing edges through which the gas emerges. The agitator rotates at speeds of the order of 100 rpm and the blades extend some seven-eighths or so across the vessel diameter, the drive being either from the base of the vessel or from the top. Performance figures offered by the company show a much more rapid degree of saturation of oxygen in water compared with a porous septum, for example a 95 per cent saturation concentration is achieved under certain conditions in twenty minutes whereas in the same

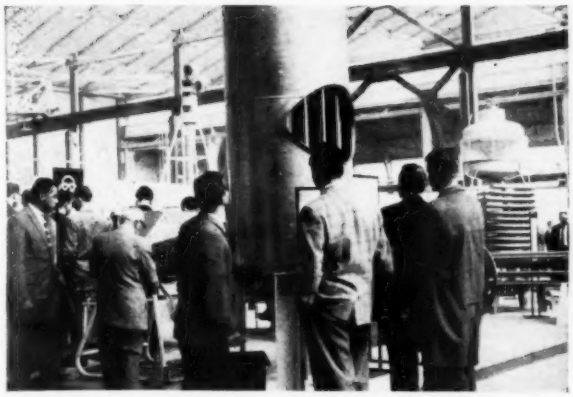


Fig. 24. An example of interest shown on the Krupp stand. Background right, an Escher-Wyss water cooler.

Fig. 25. A demonstration showing the action of the Ballast tray (Gütehöffnungshütte).

time the saturation achieved by means of a porous septum is less than 60 per cent. In the case of CO_2 in water, a final concentration of less than 2 per cent of the initial concentration is achieved in less than twenty minutes whereas a sparger pipe with agitator achieves a final concentration greater than 12 per cent in the same time. Gas cleaning, sewage disposal processes (e.g. activated sludge processes), and other biological processes are typical applications. In the chemical field hydrogenation, chlorination and gas-liquid reactions in the presence of solid catalysts are other typical applications.

Jet Mixer

The main point about a mixer shown by Samesreuther, the Sastra mixer, is the use of nozzles as the mixing elements, these being attached to arms, which in turn are supported by a hub and revolve in a container filled with the liquids to be mixed. The hub is attached to the vessel cover by a hollow tube through which the mixing liquid, fed by a centrifugal pump, passes.

Two or more systems of jets can be attached to a hub, and several hubs with jet systems can be fitted along the length of the hollow tube. The ratio of entrained liquid to driving liquid is high and the mixing effect arises from the great difference in velocity between the driving liquid and the pumped liquid, the effect being an intense turbulence at the boundary surface between two liquids.

The liquid leaving the mixing chamber does not flow through a diffuser as in the case of the jet pump, but is passed direct into the surrounding liquid. As a result a reaction occurs which causes the jet mixer to revolve round the stationary supporting pipe.

If a gas is led into the space above the level of liquid in the container, it is possible to fit appropriate suction pipes so that the jet system aspirates gas which is then dispersed in the liquid. Shaft sealing is not required in either case.

Mechanical Separation Equipment: Filters

As noted earlier in this review, this field was among the most strongly represented and several new designs appeared. In the field of filtration one of the most interesting designs (Fig. 26) was a new filter shown and demonstrated on the small scale by Krauss Maffei. Basically this machine is a vacuum disc filter in which the two-sided filter element rotates to a number of positions where the various operations in the cycle are carried out. The compression of cake stage is carried out, however, by hydraulically operated flat discs which compress the cake (pressure 20 atm.) while it is still under vacuum; the final operation in the cycle is the removal of the cake by scraper into a receptacle or upon a belt conveyor or other conveying means. A particular advantage is greater dryness of cake than produced by normal vacuum filter, for example, the final moisture content of some cakes is approximately a third less.

The machine, which is suitable for difficult filtrations, costs more than normal filters, but this can be more than offset by the reduced drying equipment capacity and in some cases the quality of the final cake, such as greatly reduced thixotropy, is an economic advantage. The machine can be provided with several cakes in parallel, size ranges are 3-16 m^2 per complete unit and power requirement is not high. A 12 m^2 unit, which is capable of handling a slurry containing g/l 320 of TiO_2 at the rate of 50 tons/day, requires 40 kw installed capacity. Other versions with the plates rotating horizontally are also produced by this company.

Borsig A.G. were another firm to show filters for handling difficult slurries. Their diaphragm filter press design consists of separate elements each containing a vertical filtering surface and an elastic diaphragm with a support which can be moved hydraulically. Pressure fluid applied to one side of the diaphragm deflects the diaphragm and compresses the cake. After the pressure on the diaphragm has been released, the latter lies loosely upon the cake and detaches itself easily when the press is opened, leaving the cake to fall out. Apart from the ability to deal with awkward dispersions, the advantages are compactness, and the large number of press elements possible in a single assembly.

Automatic Filter Press

A notable point of another filter press, shown by F. H. Schule, of Hamburg, was a mechanical transport device providing automatic or semi-automatic operation of a filter, the filter cake being removed by compressed air. A high degree of freedom from leakage has been written into the design.

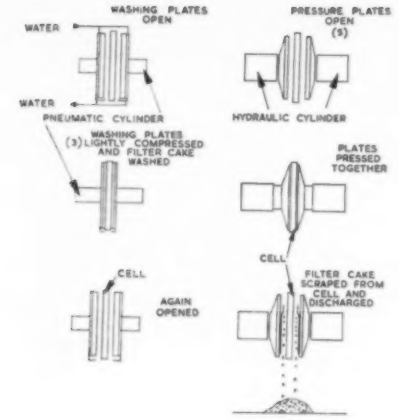
Among other novelties demonstrated by Schule was a hydromechanical manually-operated device for opening or closing a filter press, a feature being its adaptability to types of press made by other manufacturers.

Another development in the filtration field, due to Krauss Maffei, was a submersible vacuum filter, consisting of a battery of leaves, based on the original idea of Moore but possessing a completely new method of cake discharge. In operation the elements are lowered by an hydraulic mechanism into a movable tank containing the slurry. After washing, the tank is removed and the cake discharged from the element, partly by internal air pressure but also by a system of air jets placed near the lower edges of the elements. The cake discharges into a trough and is carried away by screw conveyor. Further details of this equipment are to be announced, such as capacities and so on; red-mud filtration is a particularly suitable field of application. The operating cycle can be completely automated, filtration times are rapid, generally of the order of a minute according to small-scale experiments carried out on a 3 m^2 research filter.

Particle Separation Equipment

In addition to the air swept sieve for handling materials with a tendency to agglomerate, or to become electrostatically charged, which was shown earlier in the year at Leipzig, by Alpine Company of Augsburg, novelties in this field included a machine which imitates closely the action of the hand-sieve, shown by Allgaier-Werke, its basis being the rotating sieve drum which is subjected to combined harmonic horizontal and vertical impulses (205/min). One useful result is that the coarser particles are lifted clear of the finer particles, whose passage through the sieve apertures is therefore not hindered. Where fine products have to be treated, the output is increased by the addition of rubber balls.

Another new piece of equipment in the particle separation field was shown by Wedag and consisted of a multi-cyclone circulating air separator combination. Amongst the advantages claimed for this equipment, which is suitable for cement plants, as compared with other layouts, is greatly reduced maintenance and replacement costs. In many applications the cost of replacement and maintenance is some 60 per cent or more less than in plants with inbuilt fans. Other advantages are fineness regulation possible during operation, low power loss and space and heat saving.



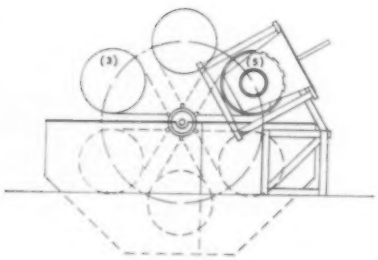


Fig. 26. A new design of filter offering much drier cakes, demonstrated by Krauss Maffei Imperial.

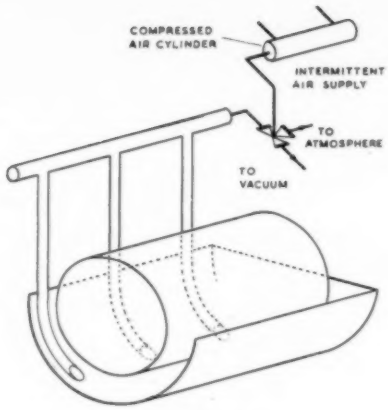


Fig. 27. A novel device shown by Krauss Maffei for agitating the trough contents of a vacuum filter. Many more tubes are used than shown here.

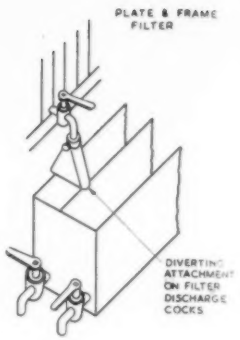


Fig. 28. Attention to detail shown on a filter press manufactured by F. Schulde.

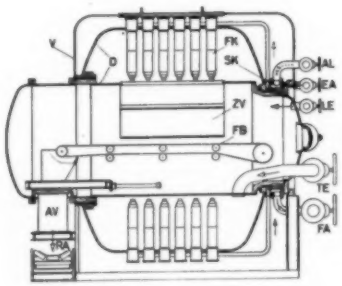


Fig. 29. The KFW-Jung pressure filter with rotating filter candles (FK), (ZV = breaking device, SK = control head, AV = discharge mechanism, RA = Residue outlet, AL = Air discharge, TE = pulp inlet, FA = filtrate outlet).

"Flexible Throat" Venturi Scrubber

Besides informing the visitor of details of application of their venturi scrubbers, which are capable of removing 0.05 micron particles with a 99 per cent efficiency, and of handling gas volumes up to 350,000 m^3/h (for example, from steel converters using oxygen) Baumco Apparatebau, Essen, introduced a modified design of this type of scrubber with a throat of cross section adjustable to the gas throughput. This overcomes the problem of separating efficiency variable with gas throughput, a matter of importance in steel making. Another novelty shown by the same company was a spent scrubbing liquid separator which is fitted within an elbow of the gas duct with considerable saving in space and equipment.

Rotary Pressure and Bed Filters

A rotary pressure filter of unusual design shown by KFW-Jung (Fig. 12), employs rotating filter candles, air discharge of cake and is made with filter areas of 5-30 m^2. The speed of rotation of the candle assembly is infinitely variable between 3 rpm and 2 revolutions per day.

Based on a new idea was a bed-filter offered by Herfilco Clichy (Seine). In this the liquid to be filtered passes upwards through the filter bed, the particles of which have been so graded that the liquid traverses layers of bed material of a steadily increasing fineness. As a result of this arrangement the flow rates achieved are stated to be three times higher and cycle length ten times greater than those obtained with traditional bed filters.

A somewhat similar filter, shown by the Duper Water Conditioning Company (Amsterdam) employs a bed of granular material which is loosely packed throughout the depth of the bed. In this case the feed takes place above and below the bed, with the filtrate leaving around the sides of the bed. Here again, higher throughputs and greater periods between regenerations are achieved, and better quality filtrates obtained in addition.

Centrifugal Machinery

In this sphere there was again a wide variety of equipment to be seen. Krupp-Dolberg for example introduced two pusher type centrifuges one with a multi-stage drum. The maximum drum size in the range is 1.4 m and the maximum output some 45 t/h. Most elements of the design are standardized and careful thought has been given by the designers to ease of maintenance. In addition this company showed a decanter fitted with a drive enabling the differential speed of the decanter screw to be varied, as well as a peeler type specially produced for the processing industries.

Continuous decanters shown by Robatel and Mulatier, Lyon, also deserve mention; features of their design being a developed centrifugal force of 2200 g, a device for accelerating the discharge of solids from the casing, and an easy means of replacing the scraping part of the screw without renewal of the latter. Other machines shown by this company included a number of hydro-extractors, the most recent in design being a continuous machine with a screw scraper of 600 mm diameter.

A number of other machines which were on view are worth noting. Thus, Braunschweigische Maschinenbauanstalt introduced a new automatically-operated continuous machine with a tilted basket. This works with a layer of cake less than 5 mm thick; feed rate is automatically controlled. Steam or gases can be fed to the machine to provide special atmospheres and an adjustable separation device is fitted in the liquor chamber to allow wash liquor to be drawn off separately. Escher Wyss drew attention to the standardization of their centrifugal components and one of the new machines displayed was a pusher-type machine with an output with some materials in excess of 50 t/h. This machine is believed to be the largest of its kind at present manufactured. Dorr-Oliver displayed their new machine for centrifuging under pressure, the Merco. A number of applications of the machine were shown on the stand, including the recovery of catalyst in a polyethylene plant. Separator AB, Stockholm also had a very impressive array of De Laval centrifugal machines including a gas-tight machine capable of withstanding pressures up to 8 kg/cm^2 at a temperature of 150°C. This, too, finds application in the recovery of catalyst in polyethylene manufacture. Another De Laval machine, designed specially for processing purposes (BRPX 213), is self-cleaning, i.e., the discharge of the sludge takes place at full bowl speed, the bowl is opened hydraulically within a fraction of a second and the motions of cleaning, opening, discharging and closing are together performed in less than one minute. Manual cleaning is eliminated. Nikex showed a supercentrifuge of very stream-

lined appearance with a centrifugal effect of 15,000 g. Capacity was stated to be 800-1300 l/h, according to the character of the material being centrifuged; ease of maintenance, replacement of bearings and bowl are features of the design. Klöckner-Humboldt-Deutz A.G. was another company to show an interesting collection of centrifugal machinery.

Complete Processing Plants and Units

An outstanding feature of the exhibition was the number of firms offering design facilities and complete processing plants and units. In addition, a number of new processes were announced.

In the former category the company operated by Dr. Erich Asendorf offered completely electronically automatic control plants for methyl formate, formic acid, formamide, hydrocyanic acid, potassium cyanide, sodium cyanide, acetocyanhydrin, amino acids, etc., as well as plants for the production of potable water from sea water and other water treatment processes. A feature of some of the plants is the use of the Luwa wiped-film reactor.

The firm of Hans J. Zimmer A.G. had an exceptional stand representing a wide range of processes. These included complete refinery complexes producing petrochemicals and plastics, plants for the recovery of useful products from agricultural wastes initiated by such processes as hydrolysis, and the preparation of furfurol, cane sugar and yeast nutrient from bagasse.

The same company is able to provide complete factories for materials such as polyacrylonitrile staple fibre.

Another organization with extensive activities in the sphere of complete plants was Dr. C. Otto and one model represented a new plant for the manufacture of HCN from ammonia and carbon monoxide. The Koppers exhibit exemplified the company's activities in plants for the manufacture of synthesis gas, water gas, gas desulphurization, continuous methanol manufacture and phthalic and maleic anhydride. The production of protective and inert gases, gas from waste products, propane, butane and an inert gas distribution system suitable for refineries were the keynote of the exhibit of J. F. Mahler.

Pintsch Bamag's exposition informed the visitor of this company's equipment for nitric acid manufacture; the company can offer plants for producing weak acid (acid concentration up to 70 per cent wt.) as well as strong acid (acid concentration about 99 per cent wt.). These are designed for the oxidation of ammonia with air or oxygen. The working pressure for the weak acid plants can be selected between zero and 7 atm.

Other equipment offered by this company includes factories based upon the electrolysis of chlorides employing a new mercury cell and chlorine processing plants for the production of hypochlorite. A plant for this purpose also makes use of waste gases containing chlorine. In addition to these activities one learned that this company's interests in the processing of fats and oils had been extended and tall oil rectification plants and plants for the separation of olein and stearin now figure in the company's repertoire.

From France came two novel processes, one employing ion exchange.

Continuous-Discontinuous Ion Exchange Column

Two alternating operational phases characterize the ion exchange process developed by Sogreah (French Atomic Energy Commission). In the first phase the solution flows upwards through the resin bed which is momentarily at rest. The resins are held stationary during this phase simply by arranging for the bed to extend beyond the liquid outlet line. In the second phase the resins move downwards as a contact bed. This is achieved by carefully controlling the liquid flow rate. The design ensures that there is no risk of co-current flow. As these two phases occur in rapid succession the installation can be considered continuous in an overall sense. The resins are recirculated and, if necessary, regenerated in a series of entirely hydraulic devices so that the risk of crushing the resins is eliminated. In the diagram of this process (Fig. 30) the symbols and numerals have the following significance: A, B, D, F and G storage, E and C, pneumatic valves, 1, 2, 3, and 4 pneumatic three-way valves, 5 and 6 resin transfer circuit pump, 7 drain valve, 8 proportional feed pump, 9 injector for accumulator 10, 10 accumulator, 11 effluent pump.

New Designs of Pumping Equipment

Among these were noted an inclined-rotor pump suitable for handling slurries and liquids containing fibrous and other solid material. At the same time as pumping the pump will disintegrate fibrous material and it is particularly suitable for use in paper-manufacturing plants. This unusual design (Fig. 12) will develop heads as high as 20 m. and little power is absorbed in any particle reduction or shredding which the pump performs. Hoelscher Maschinenfabrik are the makers.

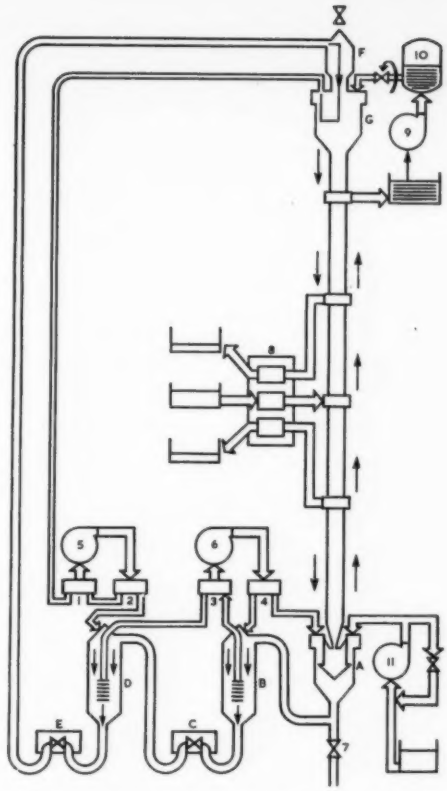


Fig. 30. A diagram of a French process for the treatment of solutions continuously by ion exchange.

In the metering field a number of pumps were to be seen, one in particular being designed for delivering very small quantities at high pressures. This pump (Fig. 13) employs the injection principle and delivers between 0.5 and 100 cc/h. The piston may take as long as 72 hours to complete its stroke when the machine has to be reset, either by hand or automatically. A modification of this pump is suitable for suspensions and is provided with small agitators in the pump body and in the suction line. This pump was one of a number shown on the Herbert Lewa stand.

Other metering pumps made by this company have been improved in respect of their head constructions and these are now available in special materials, including plastics and ceramics, as well as nickel/cobalt alloys, titanium, silver and tantalum. The range of deliveries and pressures has also been increased so that it is possible to handle up to 10,000 l/h at pressures as high as 4000 atm with a special high pressure design. The pump heads can be provided with heating in order to permit the metering of molten materials.

A squeezed-tube pump, offered by Delasco, Paris, consists of a triangular rotor carrying three rollers which come into contact with an elastic tube and compress it along an arc of just short of a semi-circle. The capacity of this pump is in the range 80-15,000 l/h although other constructions can be offered for capacities outside this range. When provided with an infinitely variable speed drive the capacity can be varied from practically zero to the highest output of which the pump is capable.

The elastic tube can be supplied in temperature-resisting materials and is usually of neoprene, hypalon or natural rubber.

Effluent Treatment Plant

Apart from showing a wide range of mechanical separating machinery Dorr-Oliver displayed a model of a plant for recovering oil from refinery waste water and also a model of a plant for treating aqueous effluent from a polyacrilonitrile plant. This latter is noteworthy since previously this problem had not been tackled successfully.

Other Dorr exhibits illustrated their activities in the fields of sugar manufacture—here a flow diagram was shown for a recent Italian carbonation and filtration plant—in pulp and paper making, including the recausticizing, brown stock washing, bleach plants in which the company specializes.

(To be continued)

Abstracts

GROUP B — HEAT TRANSFER

Burn-out Heat Flux for Steam-water Mixtures in Uniformly Heated Channels—A Review

This review discusses the available methods of predicting burn-out heat flux in systems containing flowing steam-water mixtures, and their reliability. The variables which influence two-phase burnout are considered with a view to explaining observed trends.

A further experimental study is required to confidently predict burn-out heat flux in divided fuel elements of the rod cluster type, as sufficient information does not exist for general extrapolation of results obtained from simple geometries to such a case.

Until further data become available, a simple correlation based only on the major variable, exit quality, is suggested to calculate burn-out heat flux in rod cluster fuel elements cooled by steam-water mixtures at pressures near 1000 psi.

A. F. PEXTON, U.K.A.E.A., D.E.G. Report 203 (R). Obtainable from H.M.S.O., 4s net.

Heat Transfer to Two-phase Gas-liquid System: Part 1—Steam-water Mixtures in the Liquid-dispersed Region in an Annulus

Heat transfer and pressure drop data were obtained for two-phase steam-water mixtures in the liquid-dispersed region at substantially atmospheric pressure in an electrically heated test section. The latter consisted of a vertical precision bore borosilicate glass tube fitted with a coaxial and electrically-heated stainless steel as the heat source. Two sizes of test section were used with 0.375 and 0.623 in. O.D. steel tubes inside glass tubes of 0.552 and 0.866 in. bore respectively.

Point values of the two-phase heat-transfer coefficient were determined for a range of mass flowrates and steam qualities using heat fluxes up to 158,550 Btu/hr ft^2. Three distinct heat-transfer regions were observed. Below 15 per cent dryness the mechanism of heat transfer is probably that of nucleate boiling, whilst at higher steam qualities (up to approximately 55-65 per cent) a forced convective mechanism is suggested. Beyond 65 per cent dryness the heat transfer rate decreases and in the limit approaches the value set by the dry steam coefficient.

Since fundamental knowledge of the hydrodynamics of the system is lacking, a correlation of the data in the forced convective region was sought by a modified form of the Guerrieri and Talty equation.

J. A. R. BENNET, J. G. COLLIER, H. R. C. PRATT and J. D. THORNTON, *Trans. Inst. Ch. E.*, 1961, **39**, 2, 113.

Heat Transfer to High-Quality Steam-Water Mixtures Flowing in a Horizontal Rectangular Duct

Heat transfer and pressure drop were investigated primarily at high vapour fractions and mass flow rates, where 2-phase convention-controlled heat transfer predominated.

Experimental data agreed closely with those of other studies in circular tubes. Heat transfer data were correlated by equations developed from 2 flow models: a separated-annular model and a homogeneous model.

Two-phase press drop data were satisfactorily correlated by the Lockhart-Martinelli correlation. 27 refs.

E. J. DAVIS and M. M. DAVID, *Can. J. Ch. E.*, 1961, **39** (3), 99-105.

Turbulent Convective Heat and Mass Transfer From Accelerating Particles

The rate of evaporation of acetone from single celite particles (spheres, cubes, discs, cylinders) accelerating freely in a downward concurrent turbulent air stream was studied at air velocities 40-70 ft/sec, at 410°F.

A new radioactive tracer technique, and high-speed photography, showed that the particles rotated in random manner. Heat and mass transfer data could be accurately predicted from the integration of a rate equation previously reported for stationary particles. A new characteristic dimension was satisfactorily applied to randomly rotating non-spherical particles.

I. S. PASTERNAK and W. H. GAUVIN, *A.I.Ch.E.J.*, 1961, **7** (2), 254-9.

Heat Transfer in the Condensation of Flowing Saturated Vapours in Vertical Pipes

The case of co-current flow between condensate film and flowing vapour is treated generally and it is assumed that the vapour velocity along the pipe decreases and that the friction index at the film surface changes with the Reynolds number of the vapour flow. Laminar flow is always assumed in the condensate. The equations and the results are given in the dimensionless form.

H. HARTMANN, *Chemie Ing. Tech.*, 1961, **33**, 343.

Equations for Heat Transfer to Laminar Flowing Substances in Annular Cross-sections

An analytical solution is presented for the heat transfer to laminar flowing materials in annular cross-sections. On the assumption of hydrodynamically developed flow and constant temperature at the pipe walls, and following cases are treated: (1) outer pipe insulated, inner pipe heated or cooled; (2) inner pipe insulated, outer pipe heated or cooled; (3) both pipes heated or cooled, where the wall temperatures of the two pipes may be different from each other.

The results of the calculation can be presented in simple equations. The average Nusselt number Nu is dependent on a thermal inlet flow $L/D\,Pe$, the diameter ratio $D_i\,D_e$ and a temperature index Θ which occurs only in the case of the annular cross-section heated or cooled on both sides.

K. STEPHAN, *Chemie Ing. Tech.*, 1961, **33**, 338.

Thermal Conductivity of Hydrocarbon Gases at Normal Pressures

Dimensional analysis has been applied for the correlation of the thermal conductivity of a gas to its temperature, molecular wt, heat capacity, and critical constants. Calculated values for n-paraffins, iso-paraffins, olefins, diolefins, acetylenes, naphthenes and aromatics, are an average of 2.7 per cent from experimental values. 32 refs.

D. MISIC and G. THODOS, *A.I.Ch.E.J.*, 1961, **7** (2), 264-6.

Effective Thermal Conductivity in Packed Beds

The effective thermal conductivity for liquids in packed beds has been determined from heat transfer studies. Data obtained for glass, steel, and aluminium packings are correlated by extending to liquids the method applied by Yagi and Kunii to gases. The results of this analysis are compared with results of similar studies. 18 refs.

C. D. GOPALARATHNAM *et al.*, *A.I.Ch.E.J.*, 1961, **7** (2), 249-53.

Heat Transfer in Reacting Systems: To NO_2 Gas under Turbulent Flow Conditions

N_{Re} range was 6700 to 22,000. Heat flux at inside surfaces of tubes was 300-8400 BTU/sq ft/hr, for heating and cooling. Wall temps of heater section were 100°-400°F, and cooler section temps varied from 70°-140°F. Mixed mean bulk gas temps for heating and cooling were 70°-190°F.

Heat transfer coefficients obtained were up to 14 times greater than those for the gas under frozen equilibrium conditions.

W. F. KRIEVE and D. M. MASON, *A.I.Ch.E.J.*, 1961, **7** (2), 277-81.

Effect of Intraparticle Temperature Distribution on the Catalytic Effectiveness Factor of a Porous Catalyst

Calculations show that the effect of temp is less than 10 per cent of the effect of concentration for the following cases examined: NH_3 synthesis on iron cat; SO_2 oxidation on vanadium cat; naphthalene oxidation on vanadium cat; ethylene oxidation on silver cat; CO conversion; cumene cracking on silica-alumina cat. 13 refs.

T. AKEHATA *et al.*, *Can. J. Ch. E.*, 1961, **39** (3), 127-9.

Industrial Freeze Drying of Foods Part II

The paper summarizes the factors which determine the freeze drying process: rehydration ratio, discoloration, off-flavour, vitamin loss; the heat transfer characteristics; vacuum equipment and design of freeze drying plants.

E. PETERSEN, *J. Refrig.*, 1961, **4** (3), 55-8.

Brit. Chem. Eng. Abstracts: **FOLIO No. 22**

GROUP C — MASS TRANSFER

Mass Transfer with Liquid Lithium in Circular Conduits

Forced-convection mass transfer between circular tubes and liquid lithium was investigated over a range of N_{Sch} 40-57 and N_{Re} 5550-22,500, by measuring local solution and deposition rates as a function of distance along the tubes. Results indicate that the solution process involves the parallel mechanisms of diffusion through a solid film and through occluded liquid in grain boundaries. The relative contribution of these processes changes with temperature. 19 refs.

W. N. GILL *et al.*, *A.I.Ch.E.J.*, 1961, **7** (2), 216-20.

Penetration Theory for Gas Absorption Accompanied by a Second-order Chemical Reaction

An IBM-704 computer was used to compute the penetration theory solution for the effect of a second-order irreversible liquid-phase chemical reaction on the rate of gas absorption. A simplified equation and some correction charts are presented to rapidly estimate penetration-theory solution over a wide range of variables. 20 refs.

P. L. T. BRIAN *et al.*, *A.I.Ch.E.J.*, 1961, **7** (2), 226-30.

Hold-up in Packed Liquid Extraction Columns*

A generalized correlation for hold-up of dispersed phase in packed liquid extraction columns has been derived and used to correlate the data of the present investigation in 2-in. columns, along with the reported data in 3-in. to 12-in. columns for a variety of liquids systems, using different sizes of Raschig rings, Berl saddles and Lessing rings. 7 refs.

T. SITARAMAYYA and G. S. LADD, *Ch. E. Sci.*, 1961, **XIII** (4), 263-7.

GROUP D — PHYSICAL SEPARATIONS

The Influence of Flocculation on the Operation of Vacuum Filters in Slurry Dewatering

The difficulties in dewatering fine-textured aluminous slurry on the Imperial-type vacuum filter are discussed. Lime is considered as an additional flocculating agent.

Glückauf, 1961, **97**, 129. (In German.)

Continuous Filtration of Precipitates

A review of continuous filters suitable for precipitates includes roller discharge, continuous belt drum, pre-coat drum and horizontal, top-feed and internal drum filters. Selection of filter media and methods of precipitation are discussed.

R. C. EMMETT and D. A. DAHLSTROM, *Min. Eng.*, 1961, **13** (1), 46-50.

Theories of the Operation of Continuous Thickeners

The arguments presented show that the Yoshioka construction for the determination of thickener capacity is valid if the Kynch theory applies to continuous operation, although it does not appear to be justified by considerations of minimum handling capacity. The fundamental assumption that $v_c = f(c)$, on which the Kynch theory is based, appears to be correct only in the absence of velocity gradients. It is not possible, however, to arrive at a final conclusion regarding conditions at the bottom of a thickener without further consideration and extensive experiment.

N. J. HASSETT, *Ind. Chem.*, 1961, **37** (431), 25-8.

Centrifugal Dewatering of Coal Slurries

The testing of a continuous, horizontal, solid-basket centrifuge for the dewatering of coal slurries and flotation dirt is described. Results obtained in Czechoslovakia are reported. A survey of Soviet developments in this field is given with data and illustrations. In the Czech experiments, the moisture content of coal was reduced to values between 14 and 30 per cent, which considerably increased the yield of boiler coal.

G. SEBOR and F. DEDEK, *Glückauf*, 1961, **97**, 57. (In German.)

Flash-drying System

The article describes the Raymond flash-drying system. The system can be used with or without pulverized material. Dryness and particle size can be accurately controlled.

ANON., *Chem. Proc.*, 1961, **7** (2), 14.

Deposition of Aerosol Particles in Fibrous Filters

The collection efficiency of glass fibre pads was investigated with a supercooled liquid aerosol. A filter velocity range of 0.02-20 ft/sec was covered, and the minimum collection efficiency was at 2-5 ft/sec, depending on fibre size. The data agreed with Langmuir's theory, as modified by Natanson, at low velocities where diffusion is controlling. For inertial deposition at high velocities, the measured efficiencies were lower than those predicted from theory. 11 refs.

D. G. THOMAS and C. E. LAPPLE, *A.I.Ch.E.J.*, 1961, **7** (2), 203-10.

* Author's abstract.

GROUP E — PROCESSING

Catalytic Effect on the Gasification Process in a Fluidized Bed

NaCl was the best catalyst investigated. Optimum conditions of particle size and catalyst amount were determined for the gasification rate and the degree of steam decomposition.

The catalyst represents 3-5 per cent of the bed weight, and it also improves gas composition. The effect of NaCl decreases with temperature, but it is still appreciable at 850°C.

V. I. KISLYKH and N. V. SHISHAKOV, *Gas. Prom.*, 1960, **6** (8), 15-19.

Chlorination of Low-pressure Polyethylene and its Compounding with P.V.C.

The low-pressure chlorination of polyethylene has been studied with a view to compounding the chlorinated polymer with PVC in order to improve the shock resistance of PVC, especially at low pressures. Satisfactory results have so far been obtained.

R. MIHAIL *et al.*, *Revista de Chim.*, 1961, **12** (5), 275-81.

Silicoborotungsten Acid Catalyst for the Hydration of Ethylene

This very active catalyst, which permits the application of lower temperature and pressure, has been worked out between 1957-59. The optimum process conditions have been established as 230°C temperature, 20-25 atm pressure, and 5000-6000hr^{-1} volumetric velocity. Under these circumstances the productivity of the silicoborotungsten acid catalyst is 540 g ethyl alcohol per litre catalyst per hour, and the conversion of ethylene 4.2 per cent. Diethyl ether is also formed during the reaction in roughly the same quantities as alcohol. Before recirculation of the gas stream ether is removed by freezing it out. The catalyst can be exploited for 900 hours before its performance drops to 75 per cent of its original, and then it is regenerated with only 10 per cent loss of the valuable tungsten. Besides its high activity, silicoborotungsten acid is not very corrosive and is non-volatile. The molar ratio of ethylene to water can be 0.5-1.5; any value between those limits has no effect on the productivity of the catalyst. Comparison is given with the older method, when orthophosphoric acid was used as catalyst. 8 refs.

G. K. BORESKOV *et al.*, *Khim. Prom.*, 1961, **2**, 23-7.

Securing Optimum Temperature Conditions in Chemical Reactors

Synthesis of hydrocarbons from CO and H_2 was the project of the investigations. The optimum temperature at any point in the reactor has been expressed mathematically as a function of relative catalyst volume, mole fraction of H_2 at the inlet and outlet, flow rate of reactants, prevailing pressure in the system, recirculation ratio (if any), and the total length of the reactor. Two experimental methods were used: (a) method of rectificative heat exchange; (b) method of distillative heat exchange. A short description of the apparatuses and the procedures is given. However, for completeness, one is advised to consult the given references. Both methods entailed the use of heat carriers, which were different fractions of hydrocarbons produced by the rectification of the synthesis products of CO and H_2. The more important conclusions are that the possible loading of the heat carrier is determined by the specific heat productivity of the heaters (S.H.P.H. expressed in $Kcal/m^2$ hr); heat transfer increases with the reduction of the geometrical dimensions of the packing; the variation of the heat carrier throughput or recirculation rate is the most suitable way of regulating the system; another possibility of regulation is the introduction of heat carrier into the system at different points. By choosing the right heat carrier, packing size and material and rate of heat carrier throughput, it was possible to achieve optimum temperature conditions for each point along the reactor. 5 refs.

N. I. GELPERIN and V. B. KVASHA, *Khim. Prom.*, 1961, **1**, 51-6.

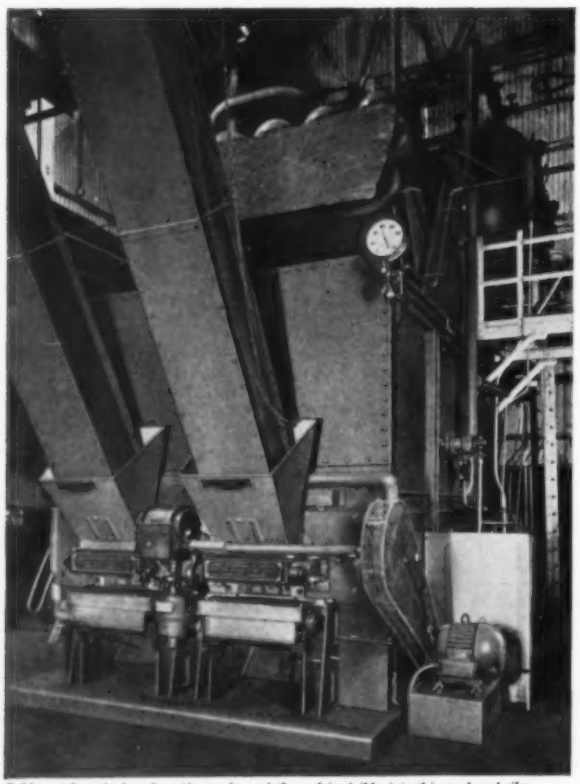
The Separation of Gamma-isomer from Technical Gammahexane, Part 2

Experimental production was started in the "AZOT" chemical plant in Jaworzno, after satisfactory laboratory work. The article describes how the factory, primarily designed for DDT production, was rearranged for gammexane. The yield of this installation, which is a temporary one, amounts to 25-30 tons of 98 per cent gamma isomer p/a. Processes of extraction, solution and crystallization are carried out in filters of a capacity of 4 m^3 equipped with mixers. Filtration is carried out on a warmed centrifuge or on a pressure filter. Gear-type pumps ensure the circulation of crystallization end-lyes and hot water at a closely regulated temperature is supplied to the jackets of apparatuses and pipes. 1 fig., 4 tabs.

J. ORLOWSKI, J. GOLEBIOWSKI and Z. GRZEBIENIOWA, *Przemysl Chemiczny*, 1960, **1**, 32-34.

Brit. Chem. Eng. Abstracts: **FOLIO No. 23**

COAL—properly used—is the cheapest fuel for the Chemical Industry



Coking stokers feed coal continuously, quietly and invisibly into this modern boiler.

Search the industrial scene—and it is difficult to find any major industry that does not use chemicals. But even in the prospering chemical and chemical processing world, sound economics are of primary importance and wise managements will always make every possible saving and every possible improvement that will help keep prices stable while satisfying—and expanding—their home and overseas markets.

BEGIN AT THE BEGINNING—THE BOILERHOUSE

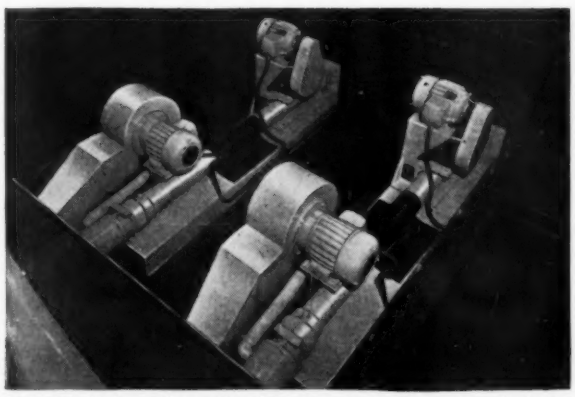
There are still some chemical plants that handicap their finances with outdated boilerhouses. To modernise other machinery while 'making-do' with inefficient boilers is to throw good money down the drain. Modern coal-burning installations can be so efficient that they will more than pay for themselves in a remarkably short time. They are, without question, the *first* essential in a chemical plant that is going to make rising profits for its management.

COAL IS THE RELIABLE FUEL

One question for any long-term planning is obvious: can supplies of coal be guaranteed? The answer is yes—without qualification. The mining industry—Britain's *largest single industry* is becoming increasingly efficient; its equipment is the best of its kind. And British coalfields contain enough coal to supply every industrial demand for centuries to come.

COAL IS CLEANER, HOTTER

Modern grading and washing methods ensure that coal is the most efficient and consistent fuel for every type of boiler—the ideal fuel for every section of the chemical and chemical processing industry. But to obtain the maximum heat at the lowest cost, coal should be mechanically stoked. A mechanical stoker automatically feeds the right amount of coal for the boiler load even when the load is varying; it burns coal at optimum efficiency all the time without the emission of smoke; and it virtually replaces the human element in boiler operation. There are many types of mechanical stokers, of which the most commonly used are the Chain Grate stoker, the Coking stoker, the Underfeed stoker and the Sprinkler stoker. Standard models are available for all sizes of boiler.



Two underfeed stokers feeding coal direct from a storage hopper into a modern vertical boiler.

OVER 80% OF BRITISH INDUSTRY USES COAL

The National Coal Board is determined that COAL shall continue to be plentiful, shall continue to keep our industrial power both dominant and progressive. You can depend upon COAL; its sources and supply are in our *own* hands, free from the fluctuations of foreign policies. Endless research by scientists and chemists working in the laboratories of the N.C.B. will ensure that coal will be increasingly profitable for its users.

DELIVERY—ON THE DOT —ON THE SPOT

The delivery of coal is today highly organised and completely reliable. Leading coal merchants have completely overhauled delivery and storage systems and are fully equipped to make sure that you get the right grade of coal when you want it and where you want it. And handling can be fully automatic. Furthermore, completely mechanised handling systems will transport coal from storage to furnace without any manual labour at all.

AND—WHEN YOU NEED IT— A NATION-WIDE FREE SERVICE

The vast resources of the National Coal Board are no further away than your telephone. At a flick of your finger, you can call upon one of the most comprehensive and efficient technical services in the world. No problem is too small or too big. You may want advice on coal quality, coal storage or coal-burning appliances or even on the siting of a new boilerhouse—whatever it is, a 'phone call or letter either to your coal supplier or to the Regional office of the National Coal Board will bring an authoritative answer to your problem.

FINANCE PLAN FOR INDUSTRY

No deposit, repayments spread over five years, low interest charges that can be set against Tax, full investment and other capital allowances, that can be claimed at once, these are the terms available to the manufacturer or businessman who wants to install modern coal-burning equipment without touching his capital resources.

Make use of the National Coal Board Industrial Finance Plan. The loans are made by Forward Trust Limited, who are members of the Midland Bank Group. A 'phone call or a letter to the Regional office of the National Coal Board will bring you full details.

SOLID FUEL—more heat at less cost—and it's British

PROGRESSIVE INDUSTRY IS GOING FORWARD ON COAL

ISSUED BY THE NATIONAL COAL BOARD

Abstracts

GROUP E — PROCESSING (contd.)

Gelatine—A Flocculant for Sludge Coal

Sludge sedimentation rates with alkalized gelatine as flocculant are usually higher than with the sodium salt of polymethacrylic acid, but lower than with starch. The preparation of solutions of gelatine and of sodium salt of polymethacrylic acid is simpler than the preparation of solutions of caustic starch. Of the three substances, gelatine is the cheapest and the most widely used.

E. Romanczyk, *Przegl. górn.*, 1959, **9**, 27-30. (In Polish.)

Gasification of Bone Anthracite

An investigation was made into the feasibility of using a conventional rotating-grate, dry-ash-removal gas producer to make producer gas from chestnut-size bone anthracite. Results showed that gas can be produced continuously from bone coal in this type of producer, provided conditions justify the development work necessary.

J. W. Eckerd *et al.*, Rep. Invest. U.S. Bur. Min., 1960, 5594. 24 pp.

Lignite Gasification Process

The USBM development of a pressure, fixed-bed, slagging gasifier operating on char is discussed. Steam and oxygen react with the char to produce gas of good quality at high overall efficiencies.

Anon., *Mech. Eng., N.Y.*, 1961, **83** (1), 53.

Fluidized Carbonization of Caking Coal

Studies on fluid-bed carbonization of pulverized coal in a steel carbonization retort enclosed in a combustion chamber are recorded. Heat carriers such as sand, iron sand and forsterite, were mixed with the caking coal in the retort; carbonization proceeded without caking trouble and the gas yield per unit weight of coal increased.

T. Iida *et al.*, *J. Fuel Soc., Japan*, April 1960, **39**, 333-43.

The Use of Phenol-free Tar Oils in Coal Flotation

Results of investigations on the use of coal and lignite tar oils in the flotation of coal slurries and fly ash are reported. The influence of acid constituents and organic bases in these tar oils on the efficiency of flotation is discussed. Results are tabulated.

J. Kmostak, *Glückauf*, 1961, **97**, 57. (In German.)

Combining Cyclone Concentration with Flotation Concentration

A plant at Dannhauser which uses combined cyclone concentration for coarse fractions and flotation for finer material is described with flow diagrams.

Anon., *Coal Base Miner, S. Africa*, 1960, **8** (10), 19-23.

New Sulphur Extraction Process Developed by Delhi-Taylor

This article describes the recovery of elemental sulphur from ores by a solvent-extraction process which offers economic and technical advantages. A diesel-grade fuel oil is the solvent and a unique countercurrent contact achieves virtually 100 per cent recovery. The process has proved economic with U.S.A. sulphur ores in a 2 ton/day plant.

Anon., *Sulphur*, December 1960 (31), 33-4.

Ion Exchange as a Continuous Process

A review has been made of the potentialities of ion exchange as a continuous process and of the contacting apparatus currently available. The apparatus is evaluated from both technical and economic standpoints, and the design theory is outlined.

K. R. Poole, U.K.A.E.A. Research Group, Harwell. Report No. AERE-R.3022. Available from H.M.S.O., 2s. 6d. net.

Shawinigan's New Fluohmic Furnace

The paper reports that a new fluidized furnace has been developed to produce HCN. A gas-fluidized bed of coke is heated electrically and becomes chemically active if the right gas is used. HCN gas is produced by passing NH_3 only, NH_3 and propane, NH_3 and methane, NH_3 and CS_2 through the bed. Volatile S compounds promote the NH_3/C reaction.

Current process uses NH_3 and an unspecified hydrocarbon gas with over 90 per cent efficiency. Other uses: production of titanium tetrachloride; desulphurization of coke; preparation of CS_2; preparation of CO.

C. R. Graham, *Can. Chem. Proc.*, 1960, 73-6.

Saline Water Conversion Report for 1960

This report contains information obtained during the 1960 calendar year.

Office of Saline Water, U.S. Dept. of the Interior.

Cyclones as Liquid-liquid Contactor-separators

The two immiscible liquids, 0.25M HNO_3/20 per cent by vol tri-butyl phosphate in odourless kerosene/uranyl nitrate, were contacted and separated in a system of two cyclones and a recycle circuit. Separation and mass transfer efficiency were good. The paper considers the possibility of using such a system as a stage in a multi-stage countercurrent solvent extraction apparatus. This system has low residence time, a favourable condition for treating enriched fissile-material solutions or highly active solutions. 17 pp.

J. W. Hitchon, U.K.A.E.A. Research Group, Harwell. Report No. AERE-CE/R.2777. Available from H.M.S.O., 4s. 6d. net.

The Use of Glass Reactors

This paper provides a detailed description of two semi-industrial units built entirely out of Pyrex and Teflon. One is a 20-litre reactor and auxiliary equipment for producing monochloracetyl chloride from thionyl chloride and monochloroacetic acid; the other unit produces pure H_2SO_4, automatically and continuously, from anhydrous SO_3 gas and water. It consists mainly of standard Pyrex equipment with Teflon joints.

X. de Bernardi, *Génie Chim.*, 1961, **85** (5), 178-80.

Photochemical Reactions in Glass

The authors briefly review the general laws related to photochemical reactions—the main sources of light, its transmission and absorption. They then briefly describe some photochemical reactions carried out industrially in glass reactors. Among these reactions are: the chlorination of benzene with mercury vapour lamps in Pyrex to give hexachlorocyclohexane; the chlorination of cyclohexane to monochlorocyclohexane in liquid phase; nitrosation of cyclohexane to give an oxime of cyclohexane (an intermediate of Nylon 6):

$$C_6H_{12} + NOCl \rightarrow C_6H_{10}NOH + HCl.$$

P. Baumgartner and F. Eschard, *Génie Chim.*, 1961, **85** (5), 200-7.

Production of Hydrogen Sulphide by Catalytic Hydrogenation of Sulphur

When sulphur is heated and vaporizes the vapour does not contain only S_2 molecules, but it is a mixture of S_2, S_6, S_8 molecules. This fact is important from the point of thermodynamical calculations. The heat of reaction of $2H_2 + S_{2(gas)} \rightleftharpoons 2H_2S_{(gas)}$ is 20,300 cal/mol, but that of $H_2 + \frac{1}{n}S_{n(gas)} \rightleftharpoons H_2S_{(gas)}$ is only about 9000 cal/mol; n = 7.1 when the vapour is saturated with sulphur. Based on a great deal of experimental work, the following specification is recommended for the catalytic hydrogenation of sulphur: tungsten-nickel sulphide catalyst having 5 mm diameter average particle size, the temperature of the gas mixture entering the reactor between 360 and 375°C, the volumetric velocity of hydrogen 1000 l/l catalyst hr, 10-20 per cent excess of sulphur (over the stoichiometric ratio). A detailed plant diagram describes the recommended technology of large-scale production. The concentration of hydrogen sulphide in the product is over 99 per cent. Heat losses from the reactor do not exceed 40 per cent and thus the process runs autothermically. Experimental results with different catalysts, catalyst sizes, gas velocities and temperatures are reported. 15 refs.

Ya. D. Zelvenskii, E. S. Nedumova and V. E. Prokopets, *Khim. Prom.*, 1961, **2**, 3-10.

Catalytic Isomerization of N-pentane on Platinum Catalyst

Step up in the production of neoprene has caused increased demand for isopentane. N-pentane was added to a recirculated stream of hydrogen and unreacted n-pentane and was isomerized under pressure. The temperature of the platinum catalyst bed (0.6 per cent platinum on a carrier) was measured at three points and these readings did not differ by more than ±1°C. N-pentane was 99.3 per cent pure in the first series of experiments and contained 12.4 per cent isopentane in the second series; electrolytic hydrogen was used throughout. The effect of variation in the hydrogen:n-pentane ratio, pressure, temperature and volumetric flow rate was studied and the following optimum parameters were found for the catalytic isomerization of n-pentane on platinum catalyst: temperature 400-420°C, molar ratio of hydrogen to n-pentane 3:1, the rate of addition of n-pentane 1 volume per volume of catalyst per hour. Under these conditions the yield of isopentane was 50 per cent and the quantity of C_1-C_4 gases below 1.5 per cent, 8 refs.

N. R. Bursian and G. N. Masliianskii, *Khim. Prom.*, 1961, **3**, 18-20.

Brit. Chem. Eng. Abstracts: **FOLIO No. 24**

BCE 125 for further information

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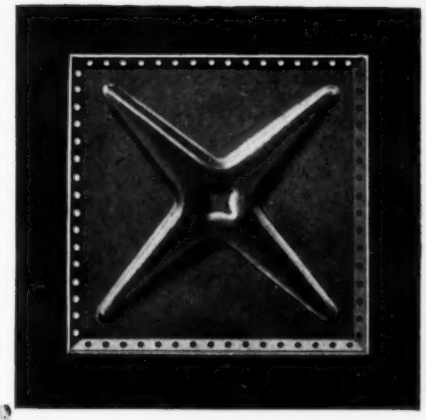

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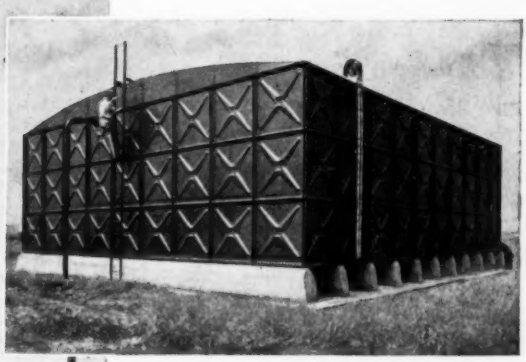

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(inset) Another covered tank for agricultural estate development 40′ × 30′ × 12′ deep capacity nearly 105,000 gallons.

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Abstracts

GROUP E — PROCESSING (contd.)

Thermal Cracking of Crude Oil

Three crude oils and two light oils were thermally cracked in laboratory experiments at various conditions of temperature, residence time, and superheated steam and coke formation in the reaction tube was studied. Shortening the residence time (to about 0·1 sec) and adding 5 times by wt. of steam increased the maximum ethylene yield; this can be further increased by further reduction in residence time, though further increases in steam will not affect many crudes. The maximum propylene yield is almost independent of residence time and steam addition. Steam addition considerably reduces coke formation from crude oil and practically suppresses it from light oils.

There was always less H_2 and especially C_2H_4 in the cracked product that corresponds to the equilibrium $C_2H_6 \rightleftharpoons C_2H_4 + H_2$. These results were in reasonable agreement with full-scale plant operation. 62 refs.

J. Wengler and H. Zeininger, *Chemie Ing. Tech.*, 1961, **33**, (5), 301-10.

Will Air Flotation Remove the Chemical Oxygen Demand of Refinery Waste Water?

Pilot-plant tests were designed to differentiate between COD reduction caused by removal of suspended matter and that caused by oxidation of materials dissolved in the water. The results showed that the COD can be more efficiently removed from refinery waste waters by the dissolved air flotation clarification process, by addition of phosphates and proper pH adjustment. Removal of oil and other suspended matter is also improved.

B. V. Prather, *Pet. Ref.*, 1961, **40** (5), 177-80.

Isoprene

Four articles in this *C.E.P.* feature cover (a) the Houdry single-step dehydrogenation process for isoprene production, with details on using isopentane and a catalytically cracked C_5 cut as feedstock, (b) an evaluation of five processes for isoprene production carried out by Goodyear, (c) the Goodyear S.D. process of isoprene production from propylene using 2-methyl-1-pentene, followed by isomerization and pyrolysis to obtain isoprene, and (d) purification of isoprene by fractional distillation.

C.E.P., 1961, **57** (5), 35-49.

Make Polyacrylonitrile Continuously

Continuous polymerization of acrylonitrile, in pilot reactors of up to 20 gal., shows that better control over particle size and molecular wt., faster reaction rates and higher yields are achieved with continuous processing. Various catalyst systems were used, both acid and iron activated. Glass and stainless steel equipment operated satisfactorily at 35-50°C. Steel equipment operated effectively at temperatures as low as 10°C with the more active catalyst systems. 15 refs.

W. M. Thomas and W. C. Mallison, *C.E.P.*, 1961, **40** (5), 211-16.

Rubber Technology

Two articles on rubber technology cover (a) solvent removable from synthetic rubbers by techniques applicable to the polymerization of new synthetic elastomers on plastics from organic solutions, and (b) dewatering and drying of synthetic rubber to moisture contents of 0·7%.

C.E.P., 1961, **57** (5), 50-4.

Investigation of the Statics of Caprolactam Extraction by Organic Solvents

The equilibrium distribution of caprolactam was investigated in such systems which were potentially interesting for the one- and two-stage extractions of caprolactam. These were: ammonium sulphate solution-caprolactam-organic solvent, and organic solvent-caprolactam-water. Trichlorethylene, azeotropic mixture of benzene and cyclohexane, carbon tetrachloride and benzene were tried as solvents for the extractions. Performance and relative cost evaluations suggest that for the two-stage extraction trichlorethylene is the most suitable solvent. However, for the production of "technical" quality caprolactam, the one-stage extraction with benzene is preferred. Empirical equations defining the various values of the equilibrium constant (K) are presented, and correlation between the number of theoretical stages required and the feed:solvent ratio for the different organic solvents is given. 16 refs.

A. G. Kasatkin, S. Z. Kagan and V. G. Trukhanov, *Khim. Prom.*, 1961, **3**, 42-8.

GROUP H — DESIGN

Nomograph for Plant Investment Costs

Using this nomograph will rapidly estimate fluid processing plant costs, based on the method of Hirsch and Glazier.

S. M. Walas, *C.E.P.*, 1961, **57** (6), 68-9.

Pumps in Atomic Energy

This survey lists relevant details of pumps which have been used for various duties connected with atomic energy in the U.K. The details were supplied by the manufacturers.

Nuc. Power, 1961, **4** (3), 68-73.

Automatic Discharge of Filter Cake

This article is intended to be a guide in selecting automatic cake discharge devices for highly compacted cakes, slimy cakes, dry heavy cakes, and tenacious cakes.

R. T. Grimm, *C.E.P.*, 1961, **57** (6), 104.

Latest Score: Reflux vs Trays

The authors present a new method, which was devised during a recent computer survey, for better estimating the reflux ratio and number of trays in multicomponent distillation. The method uses conventional calculations for minimum trays and minimum reflux as starting points, but new correlations give more reliable estimates of operating conditions. 23 refs.

J. H. Enbar and R. N. Maddox, *Pet. Ref.*, 1961, **40** (5), 183-8.

Find Best Solvent with this Chart

This chart facilitates selecting a solvent to extract a hydrocarbon from a petroleum fraction. A proper choice of solvent may eliminate distillation, or require minimum reboiler duty. The method is simple and gives estimates suitable for preliminary process design. It is illustrated with an application to a new process for extracting aromatics from paraffins.

E. G. Scheibel, *Pet. Ref.*, 1961, **40** (5), 189-94.

Solve Van Laar Equations Graphically

The authors present a graphical method for the complete solution of Van Laar equations, using "Van Laar graph paper". This procedure shortens calculation time and presents a clearer picture of the two-phase region and azeotropes.

A. L. Blancett *et al.*, *Pet. Ref.*, 1961, **40** (5), 199-204.

Refractory Suspended Construction

This paper considers two designs of refractory tile suspended roof of interest to the glass industry. Details are given on the design of metal suspension with illustrations of existing equipment.

W. S. Sinclair, *Glass Tech.*, 1961, **2** (2), 47-52.

Designing a Fluidized Adsorption System

The data presented in this paper relate to the continuous, shallow fluidized-bed adsorption system—that was part of the Wisconsin process for high-temperature N_2 fixation—which dehumidified air with silica gel. The author shows how fundamental engineering principles of countercurrent mass-transfer operations apply to the design of continuous fluidized adsorbers.

E. D. Ermenc, *Chem. Eng.*, 1961, **68** (11), 87-94.

Liquefied Gases: Cryogenic or Pressure Storage

Recent trends favour low-temperature, low-pressure storage. The author presents an engineering-economic analysis on storing liquefied gases which should help the reader to select the best system for any set of conditions.

N. R. Hower, *Chem. Eng.*, 1961, **68** (11), 77-80.

Designing Temperature-stable Reactors. Part II: Packed Bed and Stirred Tank Reactors

The design of packed bed reactors is more complex than that of a homogeneous tubular reactor (Part I) because of radial temperature gradients in the packed bed. Stability is determined by calculating temperature profiles for various assumed centre temperatures. If a slight increase in centre temperature gives a calculated decrease in wall temperature, the reactor will be unstable. Heat transfer data for the packed bed are necessary.

P. Harriott, *Chem. Eng.*, 1961, **68** (11), 81-6.

Graphical Design of Tubular Heat Exchangers

Details are given of a time-saving graphical method applicable to gases and liquids under viscous or turbulent flow conditions, provided there is no phase change. Four graphs are presented, two for pressure drop on shell and tube sides, and two for heat transfer on shell and tube sides. An example is included.

J. Starczewski, *Eng. Lond.*, 27 January, 1961, **211** (5479), 116-18.

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BCE 126 for further information

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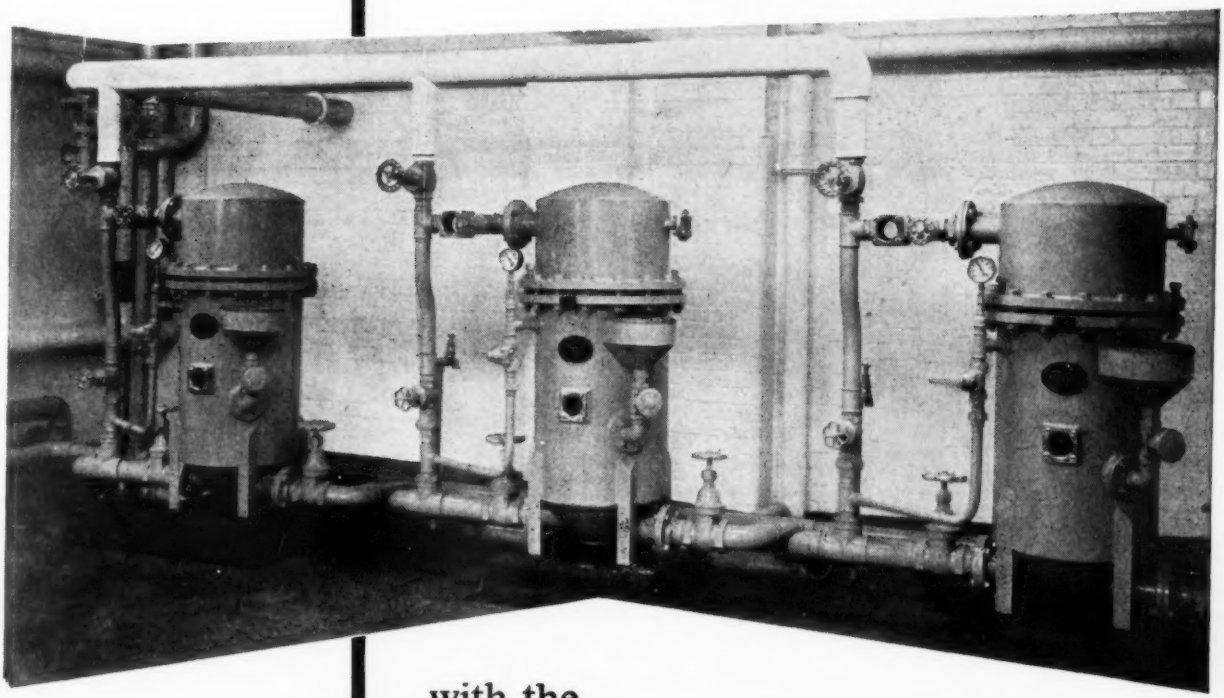

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Abstracts

GROUP H — DESIGN (contd.)

Modern Thermal Insulation Practice

The author describes many insulating materials—crumpled Al foil, asbestos fibres, calcium silicate, cellular glass, cork, diatomaceous silica, expanded ebonite and polystyrene, foamed isocyanates, magnesia, rock fibres, vermiculite—and shows how these are selected for numerous applications.

R. A. MANSERGH, *J. Inst. Heat. & Vent. Eng.*, 1961, **29**, 102-10.

Basic Ways of Reducing the Construction Costs of Aniline-dye Plants

This is a general survey well illustrated with examples. Plant items and pipework make up 46 per cent of the total construction costs; thus any decrease of the costs associated with those results in significant decrease of the total investment required. The introduction of continuous production technologies have reduced the necessary capital outlay 5-10 times in many cases. Three aspects of the continuous processes are discussed, each affecting their economics; these are: (a) kinetic conditions (e.g., sulphonation of benzene, naphthalene, ammonolysis of 1-anthraquinonesulphonic acid; (b) heat transfer (e.g., nitration or chlorination of benzene); (c) efficient mixing (e.g., neutralizations). Significant savings can be achieved also by increasing the size of the plant buildings and housing a group of plants together, thus reducing the cost of providing the services (steam, water, etc.). 6 refs.

B. E. BERKMAN, *Khim. Prom.*, 1961, **3**, 6-15.

Hydrodynamic Conditions on Sieve Trays

The graphs of experimental results show that, depending on the liquid and the gas rates, there are different characteristic hydrodynamic regions; and the liquid hold up on the trays is a function of the gas rate. The first region, the "wetting", is characterized by a relatively low pressure drop, which increases proportionally to the square of the gas velocity, at constant irrigation rate. The second region is the "loading", when the gas rate is so high that all the liquid cannot get through the holes of the tray, and a layer of liquid is observed on the trays. Hydrodynamic resistance sharply increases in this region. The top region is the region of "aeration"; and the gas bubbles through a liquid layer which consists of two parts: the lower part is relatively clear, containing some bubbles, and this is topped by a layer of froth. As the gas rate is further increased, the lower liquid layer is gradually transformed into froth. The phenomenon of hysteresis was observed between the loading and the aeration regions. Mass transfer is optimum at the region of aeration, since the surface of interphase contact is maximum in that case. Gas rate should be maintained at such a level as to secure the operation of the column in this region. Below this the efficiency of mass transfer drops; above this, excessive liquid carry-over makes operation impossible. Experiments were carried out with columns of different diameters and it was found that below a certain value the relative importance of wall effects is so great that no general correlation can be made with the bigger columns. 25 refs.

IU. G. ZELINSKII and V. V. KAFAROV, *Khim. Prom.*, 1961, **2**, 48-52.

Investigation of the Combustion Limits to Design the Preheating of Inflammable Gas-oxygen Mixtures

Ignition or self-ignition of a gas-oxygen mixture is possible only if its composition is within the lower and upper limits of combustion. However, these limits are not fixed—they are functions of the temperature and pressure and, to a lesser extent, to some other factors (e.g., materials of the surroundings, suspended particles in the gas, etc.). With increasing temperature the zone of combustibility increases, the relation being a complex hyperbolical one. The combustion limit as a function of pressure was found to be proportional to the pressure on the 0.04 exponent for paraffins and 0.09 exponent for the olefins. Stoichiometric mixtures have the lowest temperature of self-ignition. To avoid local overheating at any point along the preheater the use of flue gases is to be preferred as heating medium; electric heaters or direct flame heaters are to be avoided. Experimental results and theoretical considerations suggest that it is most favourable to use a co-current type preheater with recirculated heating medium. The heated gas-air mixture should have high linear velocity and its composition should be as far from stoichiometric as practically possible. The application of excess pressure on the heated mixture is unfavourable. 6 refs.

A. NEMETH, *Magy. Kém. Lapja.*, 1961, **4**, 185-8.

GROUP G — MISCELLANEOUS

Measurement of the Local Velocity of Brown Coal in Multiple-tube Dryers by Means of Coal Grains Labelled with Radioactive Tracers

The paper describes the method of tagging coal particles with ^{24}Na or ^{198}Au, and the equipment with which the rate of flow of tagged particles in a rotary kiln is determined.

H. K. BOTHE and H. LANGER, *Isotop. Tech.*, 1960, **1** (1), 11-13.

A Practical Approach to Fuel Economy

A description is given of the fuel-economy measures which have been applied in a large chemical manufacturing organization in Australia. Annual boiler-heat balances and efficiency records and a typical monthly boiler return are presented for water-tube boilers of 8000 to 10,000 lb/hr rating. For the year 1953 a fuel saving of about £A84,000 was achieved by economies in steam-raising and steam utilization throughout the organization.

J. M. AUSTIN, *Aust. Engr.*, 1960, **52**, 67-74.

Corrosion at High Temperatures by H_2S and S at High Concentrations

The paper reports corrosion by H_2S and S vapours at 1200°C in a sulphur furnace at Lacq. Corrosion products were determined by chemical analyses and X-ray. The sulphides formed were characterized by a different morphology but all had hexagonal or monoclinic structure and formula $Fe_{1-x}S$. Fe of phase α was present in less-corroded layers.

Similar furnace bricks and refractories, coated with a silica-alumina cement 75 mm thick mounted on steel containing 13 per cent chromium, have performed satisfactorily. This solution is now applied to other reaction furnaces at Lacq.

P. MARCHESSAUX, *Corr. et Anticorr.*, 1961, **9** (5), 160-8. (In French.)

Corrosion of Stainless Steels and Higher Alloys in Pulp Mills

These four articles contain case histories in a variety of pulping processes. Sulphite pulping solutions are frequently handled in S.S.316. Soda process digesters are usually carbon steel, with heater tubing carbon steel or 316 alloy. Kraft digesters are usually carbon steel which may be lined with alloy. Stainless 316 is used for heater piping, strong black liquor piping, and green liquor piping. Carbon steel is used for weak black liquor.

Stainless 304 and 316 are used in groundwood pulping. Hastelloy C alloy for high-strength chlorine and hypochlorite solutions and molybdenum S.S. for dilute solutions. Titanium is sometimes used for chlorine dioxide.

H. C. TEMPLETON, *Corrosion*, 1961, **17** (6), 9-28.

Effect of Sunlight on the Corrosion of Steel

Laboratory tests showed that the corrosion rate of steel is greater under a blue filter than under a red filter, provided a thin film of water covers the metal. Outdoor tests verified the laboratory results: ultra-violet light initiates corrosion sooner, and corrosion progresses faster than it would in the absence of u.v. light. Infra-red light affects the metal so that subsequent exposure to u.v. light does not produce the same increase in corrosion.

L. C. ROWE, *Corrosion*, 1961, **17** (6), 267-8.

Recent Developments in the Processing and Ultimate Disposal of High-level Radioactive Wastes

This paper summarizes the A.E.C.'s high-level problem: the types and characteristics of reactor fuel process wastes which are handled today, and which are anticipated in a nuclear power economy; high-level waste handling methods which are being used presently, and the research and development programme which is being pursued with the objective of developing a safe, ultimate disposal system for these wastes.

Paper presented at the Sixteenth Annual Purdue Industrial Waste Conference, May 1961, at Lafayette, Indiana.

W. G. BELTER, U.S.A.E.C., Washington, 25, D.C.

Gas Cleaning in the Iron and Steel Industry

The author discusses the main sources of dust, smoke and fume in the iron and steel industry, and describes equipment and methods that are used to reduce dust to an acceptable level. 24 refs.

N. PILPEL, *C.P.E.*, 1961, **42** (6), 263-70.

Mild Steel—A Material of Construction

Mild steel represents the greatest tonnage of metal used in the chemical industry. This article describes the nature of mild steel, its mechanical and physical properties and corrosion characteristics.

E. INESON, *C.P.E.*, 1961, **42** (6), 271-5.

Brit. Chem. Eng. Abstracts: **FOLIO No. 26**

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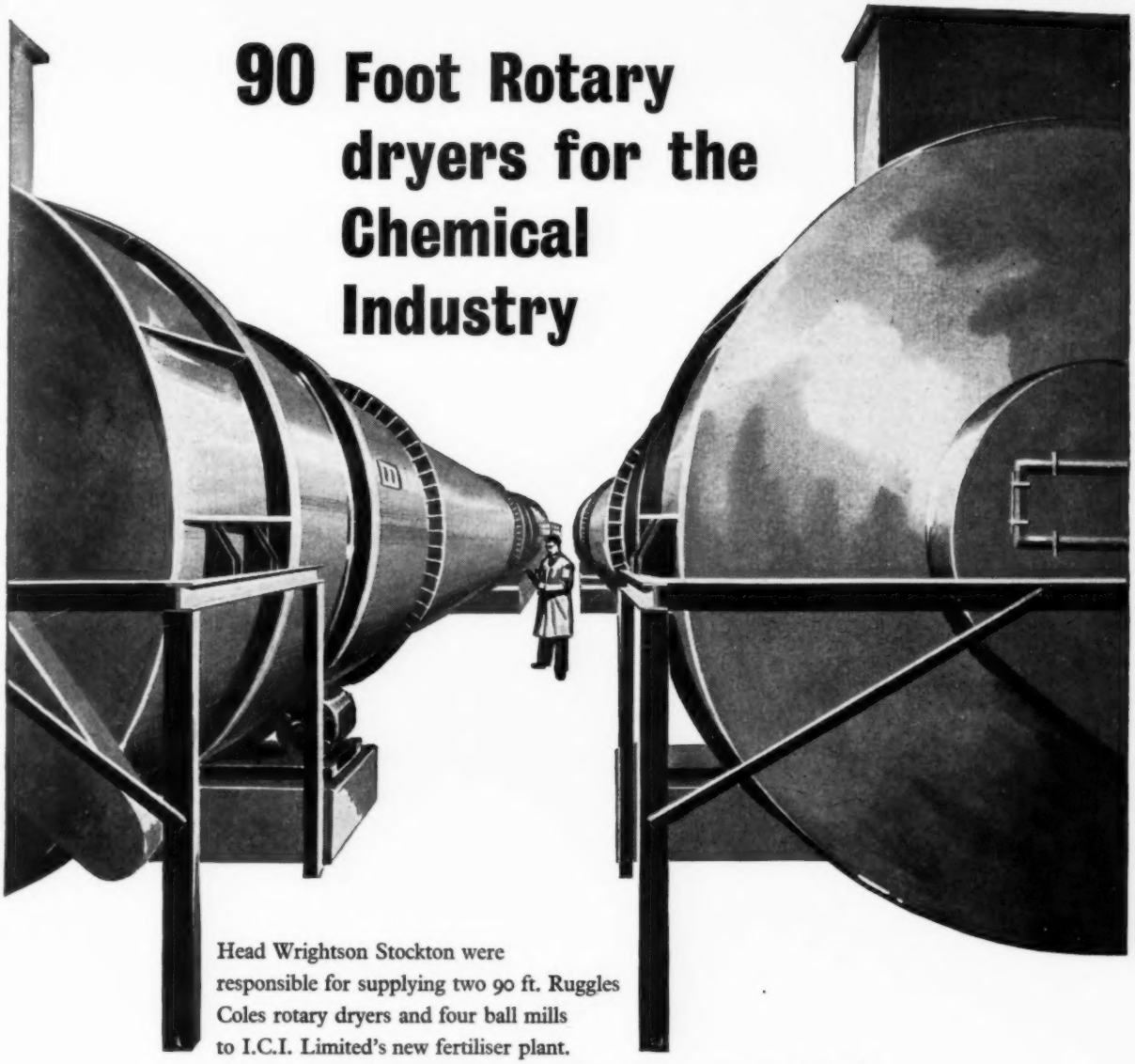

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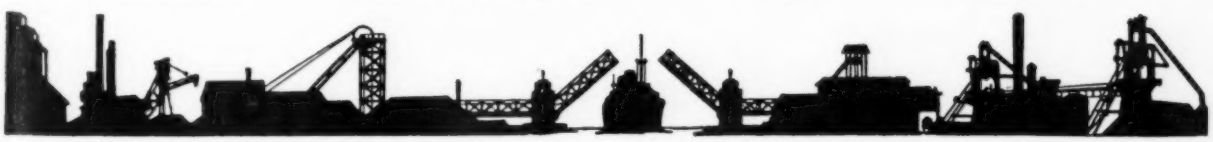


P.3722

Book Reviews

Principles of Chemical Thermodynamics
by Charles E. Reid
Reinhold Publishing Corp., New York, and Chapman & Hall, London, 1960, 306 pp., 63s.

THERE are numerous text-books on thermodynamics written from many viewpoints: the mathematician's and theoretical physicist's, the chemist's, the chemical engineer's and the mechanical engineer's, a range which shows a decreasing degree of emphasis on the theoretical aspects of the subject, and an increasing emphasis on applied problems. This new text-book, entitled the *Principles of Chemical Thermodynamics*, gives the impression of having been produced in order to introduce the American post-graduate chemistry student to the more theoretical aspects of the subject.

The eleven chapters deal with the basic concepts; the conditions of equilibrium and the free energy functions; the properties of gases and vapours; thermochemistry; the bases of statistical thermodynamics; the thermodynamics of mixtures and solutions; chemical and phase equilibria; electrochemical cells and electrolyte solutions; the thermodynamics of surfaces, and finally the systematic derivation of thermodynamic relations.

Unfortunately, much of the treatment falls between two stools: while it is of a fairly advanced nature, and therefore of necessity difficult to follow, it is not comprehensive enough to be one of the basic reference texts, such as the books by A. E. GUGGENHEIM, DE DONDER or PRIGOGINE, *et al*. An example is the treatment of non-ideal gases. The principle of corresponding states is mentioned and compressibility factors are introduced. Van der Waals equation is dealt with in considerable detail, but the virial equation is only mentioned while its fundamental implications are ignored. The book is very attractively printed and its general production is of the highest standard.

W. STRAUSS

Source Book of New Plastics: Vol. II
Edited by H. R. Simonds
Reinhold Publishing Corporation, New York, 1961, 310 pp., 72s.

THIS book represents an extremely useful guide to progress, during most of 1960, in the plastics industry in the U.S.A. The early chapters of the book are devoted to a brief survey of new plastics materials and associated substances, applications, processes and technical progress. In the major part of the work (approximately 200 pages) sixty-nine American plastics manufacturers are allocated space in which to introduce their new formulations outlining properties and uses. This section is most comprehensive. The final chapter deals with plastics research sponsored by the Federal Government.

The usefulness of the book may be regarded as somewhat restricted as far as U.K. readers are concerned, since it deals with the American field, but nevertheless this work will be a valuable current reference book for anyone interested in the plastics industry today, and in particular to those engaged in the development of plastics.

The pages are pleasantly set out and they are easy to read.

T. R. BOTT

Applied Thermodynamics
by S. H. Bransom
Van Nostrand, 1961

DR. BRANSOM'S clear comprehension of applied thermodynamics, and his appreciation of the difficulties experienced in this subject by chemical engineering students at Birmingham University, have been happily combined in the preparation of this book, in which the marked emphasis on practical applications should help to elevate the subject in the eyes of the reader from the dry-as-dust level where, regrettably, it so often lies.

In treating the theoretical aspects of his subject Dr. BRANSOM avoids those too involved mathematical arguments which in parallel texts often obscure the practical significance of the concepts discussed. He goes on to introduce in a clear and concise manner most of the topics which are normally regarded as being in the field of applied thermodynamics, there being included, for example, sections on the properties of real substances and their prediction, gas handling, physical and chemical equilibria, refrigeration and distillation. While in the space available the treatment of these and other topics is inevitably restricted, the reader is admirably prepared for passing on to more specialized treatises, to which adequate references are provided.

Especially noteworthy are the numerous well-chosen exercises, which are provided with helpful notes on their solution. Another feature is the use of many thermodynamic and other diagrams to illustrate in a concrete manner the properties and processes under discussion.

Its modest price further recommends this book, which should be of lasting value both as a textbook for students and as a work of reference for practising engineers.

K. C. SMITH

Catalysis: Vol. VII
Edited by Paul H. Emmett
Reinhold Publishing Corporation, New York, 1960, 378 pp., 108s.

VOLUME VII of EMMETT'S "Catalysis" completes the series which, with some exceptions, covers the major field of catalytic processes employed in industry. This volume deals with cracking catalysts, catalytic hydration, dehydration and oxidation. The first chapter is a continuation of the section on cracking catalysts of Volume VI and covers the properties and nature of the various silica-alumina catalysts used for the production of high octane petroleum products. This is followed by a chapter on catalytic dehydration and hydration which contains description of now outdated processes for the dehydration of alcohols and the more important in recent years, reverse processes for the synthesis of alcohols by the hydration of olefins. Other hydration reactions, e.g. that of acetylene to acetaldehyde, acetic acid and acetone are also included. The oxidation of hydrocarbons viz. benzene, toluene, xylene, naphthalene and olefins is treated fully with information from the most recent publications. There is a separate chapter on other catalytic oxidation reactions including oxidation of ammonia, carbon monoxide and sulphur dioxide. The last two chapters contain a discussion on the mechanism of catalytic oxidations.

Catalysis is one of the branches of chemistry which to a large extent employs an empirical approach, where practice is still ahead of theory and where it is possible to arrive at results without fully understanding the underlying mechanism. For this reason, most of the knowledge on this subject is kept under cover by industrial establishments and only a limited amount of information is available in the published literature. The present volume, in line with the rest of the series, is a thorough review of the existing literature with some personal contributions by the authors. In some cases, this amounts to a complete description of the mechanism, reaction conditions, kinetic data and catalyst manufacture and in others, it is hardly more than sufficient to stimulate the appetite of the reader. It is regrettable that this valuable series finishes without forming a complete treatise on catalysis. There are fields of catalytic reactions which have been omitted or hardly touched upon, e.g. polymerization, halogenation, liquid phase catalysis.

This book has maintained the high standard and reputation achieved by previous volumes. It will be found indispensable by chemists and chemical engineers as a secondary source of literature on chemical catalysis.

SHORTER NOTICE

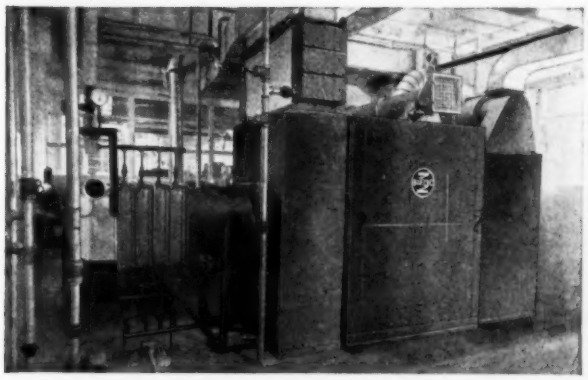
Nuclear Reactors Built, Building, or Planned in the United States as of Dec 31, 1960
U.S.A.E.C., Washington, D.C. Gratis.

THE Atomic Energy Commission has published in booklet form, a compilation of *Nuclear Reactors Built, Building, or Planned In The United States As Of December 31, 1960* (TID-8200 [3rd Rev.]), which is available, without charge, from the Office of Technical Information Extension, U.S. Atomic Energy Commission, P.O. Box 62, Oak Ridge, Tenn.

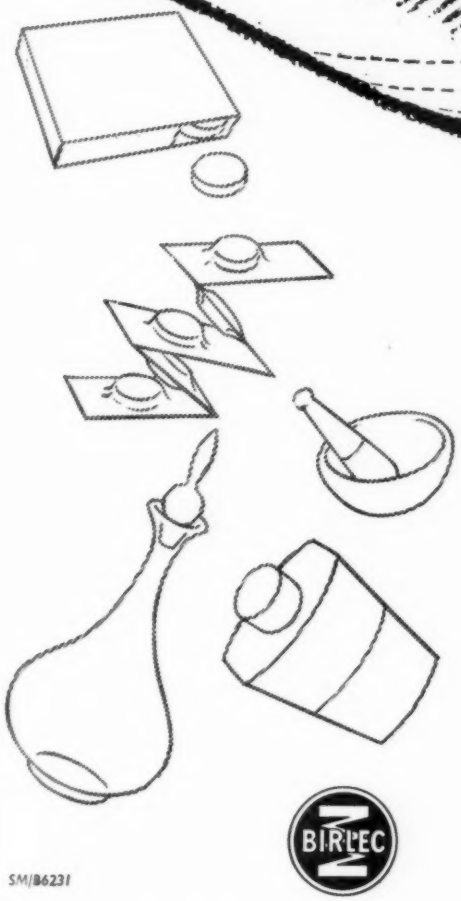
The 26-page booklet contains tables listing Civilian Reactors (domestic), Military Reactors, Production Reactors, Reactors For Export, and Critical Assembly Facilities. The compilation of reactor projects and facilities is published semi-annually, as of June 30 and December 31. The December 31 tables are also carried as an appendix in the Commission's Annual Report To Congress (Appendix 12, page 433 in the 1960 Report).

DRY HYGROSCOPICS

Model CO Dehumidifier installation at Reckitt & Sons Limited, Hull, for their Steradent process room.



Many chemicals and pharmaceutical products are harmed by atmospheric moisture. Damp weather may spoil both the product and the smooth flow of the production processes if atmospheric humidity throughout the plant is not controlled. Birlec Direct Dehumidifiers offer a simple and highly efficient means of holding the relative humidity of a process room or storage enclosure at a safe low level.



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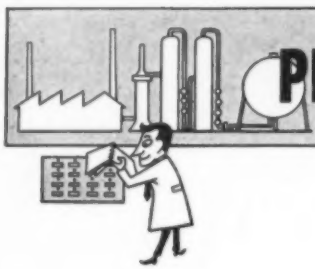


PROCESS ENGINEER'S NOTEBOOK

Support Design for Large Transparent Plant Model

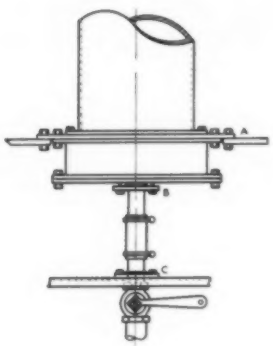


Fig. 1

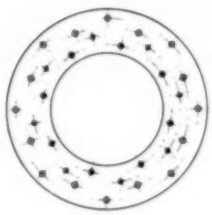


Fig. 2

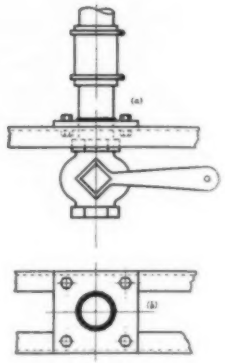


Fig. 3

WHEN building transparent plant models using glass and plastic materials, careful attention must be given to support systems.

Recently it was necessary to construct a transparent model plant comprising, essentially, a flanged 2-ft-dia. perspex column, a comparatively heavy steel base section (to be easily removable), a centrally situated 3-in.-dia. glass offtake pipe from the base section, and a heavy 3-in. port size plug cock valve. A schematic view of the model is shown in Fig. 1.

Three positions were chosen for special support provision:

(1) the main support (position A) at the junction of the fragile perspex cylinder and the heavy base section;
(2) the glass offtake pipe support (position B); and
(3) an independent support for the heavy plug cock valve (position C).

The requirements of the main support (A) were that it should be attachable to the platform of the surrounding structure and support safely the perspex cylinder and heavy base section so that either unit could be removed independently of the other. These requirements were met by using a separate mild steel flange (3 ft 4 in. o.d., 2 ft. i.d., $\frac{3}{4}$ in. thick) as a support base. Fig. 2 shows that the flange was provided with:

(1) an outer ring of bolt holes (8 × $\frac{11}{16}$ in. dia., P.C.D. 3 ft 2 in.) for bolting directly to the platform centrally above a 3-ft-dia. hole;
(2) a ring of studs (8 × $\frac{1}{2}$ in. B.S.F.; P.C.D. 2 ft 3$\frac{1}{2}$ in.) on its upper side to connect it with the 2 ft 6 in. dia. base flange of the 2-ft-dia. perspex column;
(3) a ring of studs (8 × $\frac{1}{2}$ in. B.S.F., P.C.D. 2 ft 5$\frac{1}{2}$ in.) on its underside for carrying internal fitments in the base section; and
(4) a ring of bolt holes (8 × $\frac{11}{16}$ in. dia., P.C.D. 2 ft 9$\frac{1}{2}$ in.) for bolting to the upper flange of the base section.

At position B the short length of 3-in. glass offtake pipe was connected quite simply to the bottom flange of the base section using a commercially obtainable clamping arrangement comprising a clamping flange, insert ring and gasket with three equally spaced studs projecting from the base flange.

At position C the problem was not only one of supporting the comparatively large valve weight, but of ensuring that no untoward laterial strain would be imposed on the glass pipe when opening and shutting the valve. The requirements here were met by employing the support system shown in Fig. 3. The valve was supported independently of the rest of the unit, and, since no flanged type of valve was available, an indirect system had to be used. A length (6 in.) of 3-in. standard pipe (a) threaded at one end was welded in a centrally cut hole (3$\frac{1}{2}$-in. dia.) in a square steel plate (8 × 8 × $\frac{3}{8}$ in. thick) (b) so that about 1 in. of pipe thread length protruded from the underside. The plate (b) was then bolted (4 × $\frac{1}{2}$ in. B.S.F. bolts) in a horizontal position to the two parallel stringer beams (2 × 2 in. angle) which extended laterally across the framework just above the desired valve position and 8 in. apart. The stringer beams were bolted to cross-members at opposite ends of the main frame. The valve was then screwed on to the lower end of the 3-in. steel pipe; the upper (unthreaded) end of the steel pipe was connected to the lower end of the 3-in. bore glass pipe using flexible hose secured with screwed clips. By employing this system, substantial support was given to the valve and possibilities of damaging the glass pipe by leverage on the valve were eliminated.

Preventing Hold-up Through Stickiness

APART from the many examples of economies effected by the use of fluorocarbon as a material of construction for certain components of process equipment, a number of cases have been reported* where some successful applications have been made to reduce hold-up of a finished product through stickiness. Normally, sticking process material would have to be manually removed from equipment and this is often a disagreeable and sometimes a hazardous operation.

A notable example illustrating the advantages of using fluorocarbon-lined equipment is in the manufacture of rayon. Considerable time and labour were involved in cleaning out a reaction vessel called a baratte, and at one plant a lining of P.T.F.E. was installed in the barattes to facilitate cleaning. The shortened clean-out time reduced the operating labour force by one-third and added more than 5 per cent to plant productivity.

There was an unexpected benefit. After lining all the barattes, plugging of the filters in later process steps becomes noticeably less frequent, resulting in reduced maintenance.

Sheets or films of P.T.F.E. resins are also being used as linings for troughs and feeders for fertilizer mixing plants to prevent retention of materials upon equipment walls and screens.

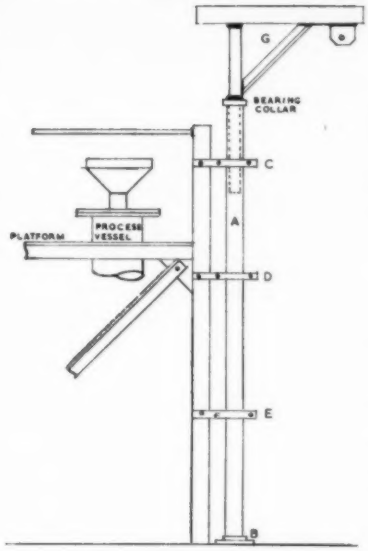
* Paper No. 61-MPE-1 by R. D. PILLSBURY, JR. Presented at the Maintenance and Plant Engineering Conference, Worcester, Mass., April 10 and 11, 1961, of The American Society of Mechanical Engineers.

An Extemporized Hoist Support

WHEN an existing framework had been modified to accommodate a small pilot plant handling 1 in. lump material, it was found necessary to erect a hoist support so that the containers, holding approximately 150 lb of the raw material, could be raised to the charging level.

This support was simple to construct and its design was such that if and when a more permanent support was made available then it could be dismantled and much of the material re-used. The support can be used for many lifting problems, both in construction and operation, provided that a sound footing and at least two vertical clamping points are available.

A long piece (12 ft) of standard pipe (2½ in.) screwed at one end was used for the main support (A); the screwed end was provided with a standard screwed flange (B) and this served as a base to the column, which was then erected in a vertical position. The vertical clamps C, D, E, made by forging 1 in. × ¼ in. steel strips, were, in this case, bolted to the



platform stanchion.

The swinging hoist arm G was made from a length (3½ ft) of standard 2½ × 2½ in. channel and a length (6 ft) of standard pipe (2 in.).

The pipe having been welded to the channel, as shown in the diagram, was braced by a length of 1½ in. × 1½ in. angle. A fish plate with an eye hole for the hoist hook was then welded to the end of the channel, and a stop collar welded to the pipe just below the bracing jib.

The (2 in.) pipe of the arm fitted snugly within the main column pipe (2½ in. dia.) and was able to rotate firmly but smoothly.

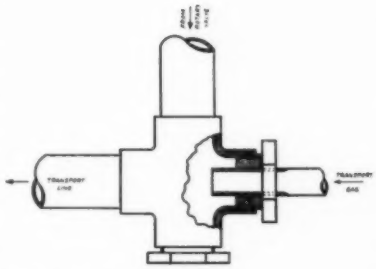
With this system it was possible to hoist the materials to charging level, then to swing them immediately above the charging vessel for tipping. The dimensions of the materials used in the design of a hoist of this kind would have to be carefully selected if it were to be used for lifting very heavy weights.

W.H.N. and G.O.D.

Improved Solids Pick-up in Low-velocity Transport Systems

IN low-velocity pneumatic transport systems troubles frequently arise at the point where the solid material meets the conveying gas. In this region there exists the largest pressure gradient of the system, since the solid has to be accelerated from its zero entry velocity to conditions of stable conveying velocity. If it is necessary to employ a conveying medium velocity not much greater than the terminal velocity of the largest particles (e.g., as may be dictated by downstream process conditions or the need to avoid abrasion difficulties) dune formation and blockage can become quite serious at the point of solid entry.

The sort of problem arose recently with a simple pneumatic transport system handling an abrasive granular material. The solid was being fed from a hopper, through a rotary valve into an initially

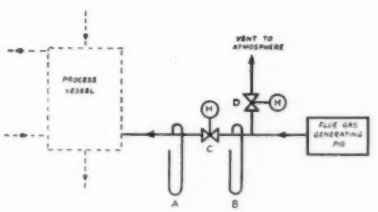


horizontal length of 3-in.-bore transport line. Frequent stoppages and irregular operation were caused by settling out of the larger particles near the point of entry. The problem was overcome by introducing the transport gas as a comparatively high velocity jet just below the discharge end of the rotary valve instead of as a full-bore supply. The diagram shows (in part section) the arrangement used. The rotary valve delivery pipe entered the top limb of a 3-in. B.S.P. cross; the lower limb was sealed with a 3-in. B.S.P. plug. The 3-in. B.S.P. transport line connection was made to the left-hand limb; transport air was supplied at the right-hand limb through a 1½-in. B.S.P. pipe carried in a 3in. × 1½ in. B.S.P. reducing bush. Thus, over the critical "pick-up" section of the transport line, a localized high velocity jet was created and, additionally, a comparatively low pressure region induced at the underside of the rotary valve. The combined result was an easier flow of solid to the transport line and more efficient solids pick-up in the transport line, eliminating the troubles experienced hitherto.

Pressure Equalization Method

FOR a heat-treatment process using hot flue gas generated in a gas pig it was required to admit the flue gas intermittently to the treatment vessel which was maintained at a pressure of several inches water gauge. It was essential that the "batchwise" introductions of flue gas should be accomplished with the minimum of pressure fluctuation.

This operation was achieved simply by the use of two manometers and manual operation of two plug cock valves. The diagram shows the system employed. 24 in. w.g. manometers, A and B, were installed, one on each side of the plug cock valve, C, connecting the flue gas



delivery pipe to the treatment vessel. A further plug cock valve, D, was used as a venting valve in a branch line from the main flue gas delivery pipe.

When flue gas was not being admitted to the treatment vessel, valve C was shut, valve D was open, thus venting flue gas to atmosphere. Under these conditions manometer A indicated the pressure of the process vessel; manometer B indicated a pressure near atmospheric pressure. When it was required to admit flue gas to the vessel the following procedure was adopted:

Vent valve D was slowly and carefully closed until the manometer reading on B had become almost equal to the reading of A. At this point the valve C could be opened and the vent valve closed, thus allowing flue gas to flow into the treatment vessel without surges in pressure.

FILM COEFFICIENTS FOR STEAM CONDENSING UNDER VACUUM

by **D. S. DAVIS** University of Alabama

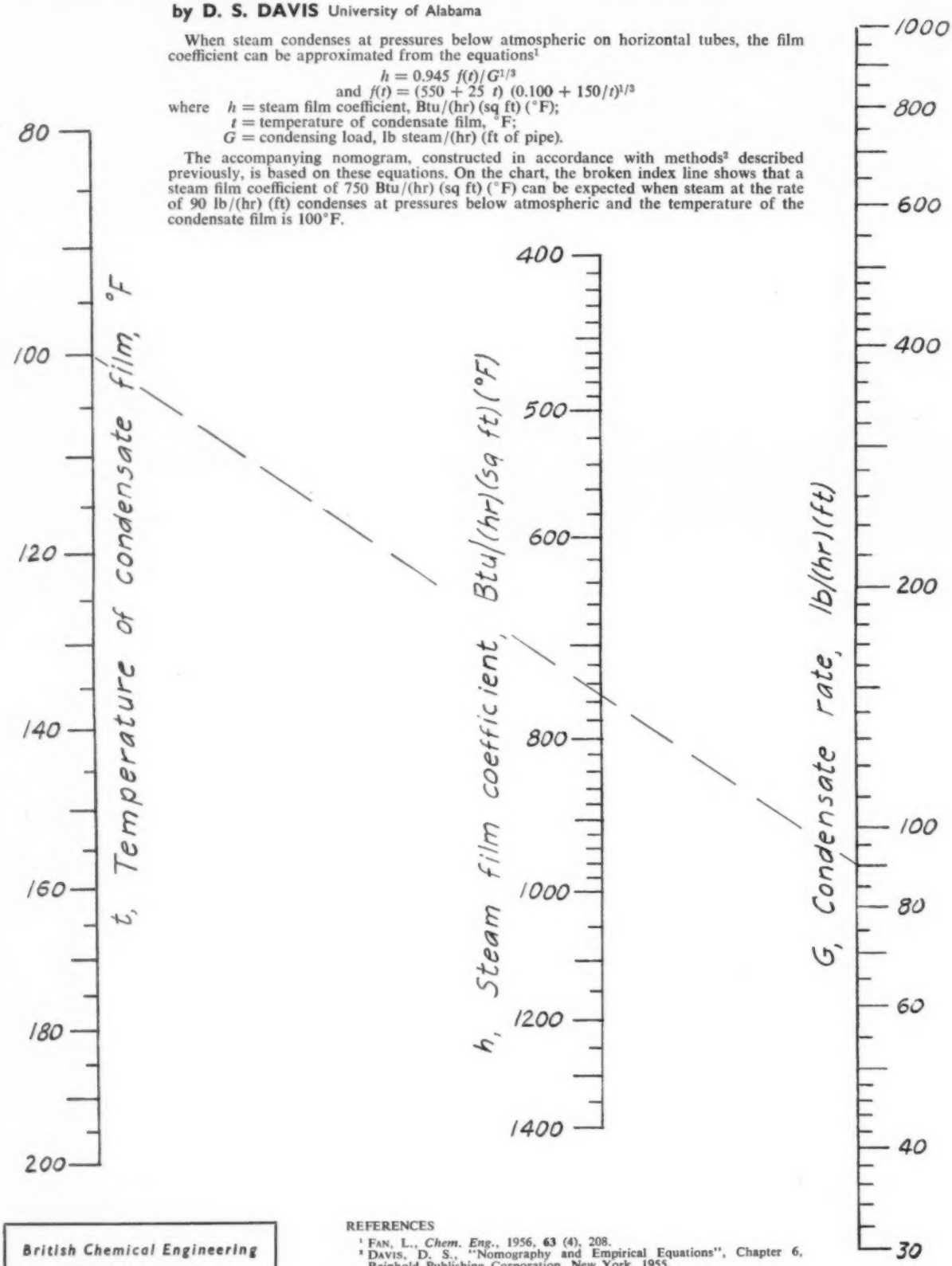
When steam condenses at pressures below atmospheric on horizontal tubes, the film coefficient can be approximated from the equations[1]

$$h = 0.945\, f(t)/G^{1/3}$$

$$\text{and } f(t) = (550 + 25\,t)\,(0.100 + 150/t)^{1/3}$$

where h = steam film coefficient, Btu/(hr) (sq ft) (°F);
t = temperature of condensate film, °F;
G = condensing load, lb steam/(hr) (ft of pipe).

The accompanying nomogram, constructed in accordance with methods[2] described previously, is based on these equations. On the chart, the broken index line shows that a steam film coefficient of 750 Btu/(hr) (sq ft) (°F) can be expected when steam at the rate of 90 lb/(hr) (ft) condenses at pressures below atmospheric and the temperature of the condensate film is 100°F.



British Chemical Engineering
NOMOGRAM NO. 61

REFERENCES
[1] FAN, L., *Chem. Eng.*, 1956, **63** (4), 208.
[2] DAVIS, D. S., "Nomography and Empirical Equations", Chapter 6, Reinhold Publishing Corporation, New York, 1955.

DANGER

Skate on the thinnest ice: step on the conductor rail: cross Piccadilly Circus from Northwest to Southeast: but remember that **ASSOCIATED LEAD** are the most reliable and economical suppliers of **LEAD, TIN, ANTIMONY AND THEIR ALLOYS; 99.999% PURE LEAD, TIN AND ANTIMONY; SOLDERS; ANTI-FRICTION MATERIALS; ANTIMONIAL LEAD; CABLE ALLOYS; LEAD SHEET AND PIPE; DENSE LEAD SHIELDING FOR NUCLEAR WORK.**

The dangers involved in forgetting this simple fact are too numerous to name: but, to put it shortly, it is a matter of profit and loss.

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PLANT EQUIPMENT NEWS

B.M. Residual Chlorine Recorder

This new recorder operates on the bimetallic cell principle and its design is less complicated than that of instruments using colorimetric measurements.

Sample water is received and measured in a small perspex chamber. The water then flows by gravity to a larger perspex chamber in which it mixes with the reagent. The reagent used is a simple buffer solution containing small amounts of a compound (BM 18) which prevents mould growth without affecting the analysis.

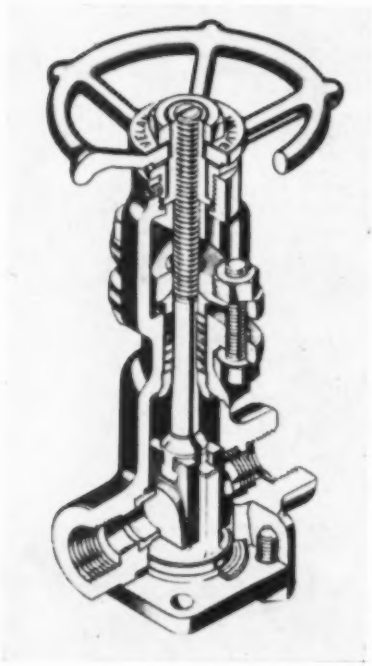
The water-reagent mixture then flows to the BM cell, where the free chlorine is measured by two electrodes which produce current in proportion to the chlorine concentration. These electrodes are automatically polished with a mild abrasive which is retained in the unit.

Where total chlorine as well as free chlorine are required, a second reagent vessel is fitted and potassium iodide solution is used. **The Patterson Engineering Co. Ltd., 129 Kingsway, London, W.C.2.**

BCE 167 for further information

Range of Valves with "In-line" Servicing

A new kind of valve is now being made which can be tested and fully serviced while still connected in the pipeline. Gate and globe types of forged steel, bonnetless design are in production. All types are available with flanged, screwed or welded ends and valves made from stainless steel or other materials for special services can be supplied.

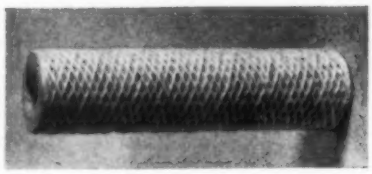


Gate Type. These are available as inside- or outside-screw type in a range of standard bore sizes from ½-2 in. They are suitable for working pressures up to 600 psi at 900°F (2000 psi cold, non-shock).

Globe Type. These are outside-screw type available in vertical or oblique patterns in bore sizes from ½-3 in. Although designed primarily for extreme temperatures and pressures (up to 2500 psi at 1100°F), they are reasonably priced and the resultant savings in maintenance and operating costs make them a good proposition for both low- and high-pressure applications. They can also be supplied as stop, stop-check, needle or flow control valves. By ingenious design and complete interchangeability of parts, it is necessary only to change the stem and disc to convert one type to another. **Newman, Hender Group, Woodchester, near Stroud, Gloucestershire.**

BCE 168 for further information

Filter Cartridge



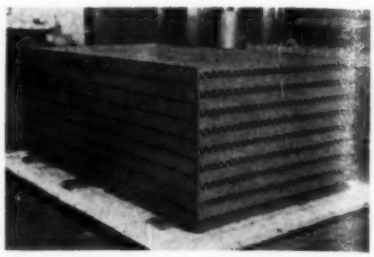
This is a depth-type unit suitable for a variety of fluids. The cartridge is manufactured by a technique that integrates two separate materials; one, a layer of fibre chosen for its filtering properties, the other a winding yarn chosen for its strength. These two materials are applied separately but simultaneously around a heavy gauze core with the filter fibres uniformly interlaced as the winding yarn is applied.

The cartridges are available in densities of 10, 25, 50 and 75 microns on either a tinned-steel or stainless-steel core. **Morris & Ingram, 114 Kingston Road, London, S.W.19.**

BCE 169 for further information

Finned Heat Exchanger in Carbon

A recent extended-surface exchanger has been developed with the object of providing an extremely corrosion-resistant apparatus to the chemical and ancillary industries. It is constructed of impregnated graphite. Its design is intended to make easy the change from the water-to-air cooling of corrosive solutions. For this purpose, the apparatus is equipped on the air-side with relatively high fins in a comb-like arrangement, thus producing a large surface for air cooling. The opposite side of the plates contains smooth channels through which flows the liquid to be cooled.



The apparatus is compact for its 50 m^2 of surface, so that little space is required. A space of $2 \times 2 \times 1$ m will accommodate the exchanger—an exceedingly small space for an apparatus, constructed from electrographite, since, compared with metallic constructions, greater wall thickness is required. The medium to be cooled is passed through the apparatus transversely to the air. The velocity of liquid-flow has little effect on the overall heat transfer coefficient, which is in the range 80-100 kcal/m^2 hr °C with an air pressure drop of 200-500 mm w.g., depending on the construction of the apparatus. **Siemens-Plania-Griesheim in Meitingen über Augsburg, West Germany.**

BCE 170 for further information

Fibre-glass Pressure Vessels use Anhydride-cured Resins

Based upon methyl anhydride-cured epoxy resin reinforced with continuous glass fibres, a recently introduced method of construction employs a system of criss-cross filament winding, in which the individual glass fibres are applied on to a mandrel a hundred strands at a time. The angle at which the individual fibres cross is closely controlled, because it affects the proportion of resin taken up in the final product, and therefore has an important bearing upon the final strength.

Vessels made in this manner are capable of sustaining hoop stresses of 120,000 psi, and constructions up to 78 in. diameter and 30 ft length are possible.

Typical applications have been storage bottles for nitrogen and concentrated sulphuric acid (a fluon liner is used in such a case). A typical nitrogen cylinder made by this technique was 8 ft in length, 5 in. in diameter and weighed 32 lb, inclusive of end fittings. Operating pressure was 3000 psi. For sulphuric acid small cylinders have been made capable of sustaining an operating pressure of 150 psi.

The reinforced material, known as Hystran, surpasses other light materials, such as aluminium and titanium, in both lightness and strength/weight ratio. Thus, while aluminium has a density of 0.097 lb/cu in., Hystran has a density of 0.072 lb/cu in. The tensile strengths are 80,000 and 165,000 psi respectively. **Dage (G.B.) Ltd., La Casita, Heronsgate, Herts.**

BCE 171 for further information

SUPER-D-CANTER

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"Tonight, number seven will be your lucky number at the tables, M'sieu. The croupier is my brother, M'sieu. But I have it on even better authority that Sharples are giving a complete engineering service on any process connected with separation. Thank you M'sieu. Vive la separation."

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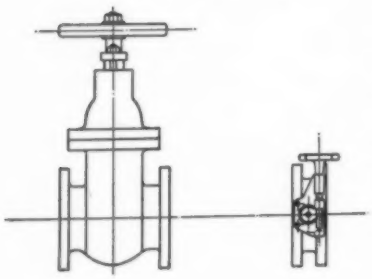
PLANT EQUIPMENT NEWS

Pivoted Disc Valve



This pivoted disc valve has a spheroidal seating-surface which is offset from the centre line of the spindle, combining both angular and axial movement in its closing action, to give positive, compressive seating over the entire periphery. The seat is adjustable, and is made from a tough material of high flexibility bonded to a rigid metallic core. It is locked in position by a screwed retaining ring, which provides axial adjustment to positioning the seating surface accurately in relation to the disc. The resulting spot-tight closure can be maintained over a long period of service.

The valve is particularly adaptable to automatic operation by pneumatic, hydraulic and electrical control, including automatic positioning where required. Extremely low operating torque allows reductions in the size, power and cost of actuators. Maximum working pressure 150 psi; maximum working temperature 212°F. **B. W. Valve Co. Ltd., 140 Granville Street, Birmingham, 1.**

BCE 172 for further information

Versatile Crushers

This design of crusher can be supplied with one of three types of crushing chamber design, depending upon whether a coarse, intermediate or fine product is required. It can handle scalped feed up to 4¾ in., 2¾ in. and 1¾ in. respectively.

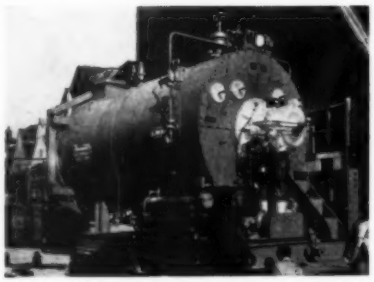
A feature is the provision of instant hydraulic adjustment, so that when oil is pumped into or out of the hydraulic cylinder, with which the machine is equipped, the mainshaft assembly is raised or lowered, changing thereby the crusher setting. During operation the crushing cone is automatically lowered to release uncrushable matter from the crushing chamber, and then resets itself to its original position. Lubrication facilities have been given especial attention; thus three independent lubricating systems are incorporated in the unit. **Allis-Chalmers Manufacturing Co. Ltd., Milwaukee, 1, Wisconsin, U.S.A.**

BCE 173 for further information

"Powermaster" Packaged Boilers

A guaranteed thermal efficiency of 83 per cent for a steam output of 13,800 lb steam per hr can be achieved by a packaged boiler, one of the recent 'Powermaster' series (Model 400). It is 19 ft 3 in. long, 9 ft wide and 13½ ft high and weighs about 40,700 lb. The model 600 produces 21,000 lb steam per hr.

Automatic and safety control are fitted as standard on every unit, and all the ancillary equipment is the responsibility of one supplier. Each unit is given a thorough trial under specified conditions of feed water and fuel in the works.



The complete range of "Powermaster" models comprises 17 models with outputs from 517 to 24,000 lb/hr.

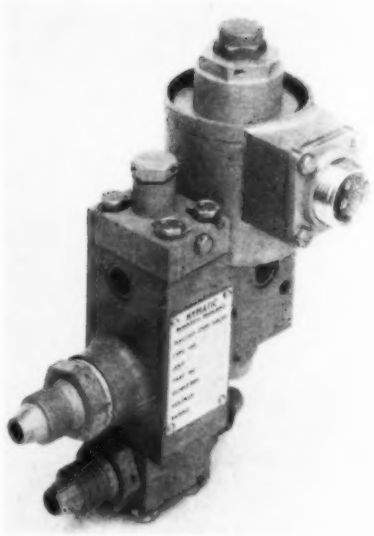
They can be supplied as low-, medium- or high-pressure hot water boilers, either flooded or with steam space, or can be arranged to deliver steam up to 250 lb/sq in. Suitable oil fuels range from diesel oil up to 3500 sec Redwood No. 1 in all but the smallest sizes, town gas, or an oil/gas combination. **G.W.B. Furnaces Ltd., Dibdale Works, Dudley, Worcestershire.**

BCE 174 for further information

New High-pressure Solenoid Valve

For high-pressure gas a new solenoid valve having an extremely low leakage has been developed which allows venting of the downstream system when the valve is closed.

The valve is designed for a normal working pressure of 4500 psi. It was originally developed for a special armament application that required perfect operation under adverse combinations of temperature, pressure, accelerations and voltage. In fact, this was so important that the valve was series tested in production at −54°C. In addition, the valve has to be virtually leakproof in that at −65°C the leak is less than 0.0004 cfm.



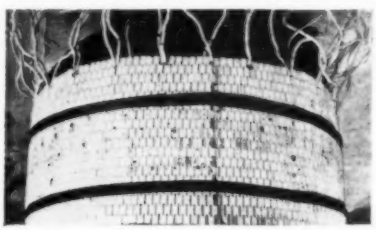
A version of the new valve has a high-speed response time of less than 35 milliseconds. In standard form it has a response time of 150 to 300 milliseconds. It has a temperature range of −45 to +70°C and will work unrestricted over the full range of accelerations of ±12 g in all cases. It has a through area of ⅛ in. BSP size and weights 2¼ lb.

Included amongst its applications are remote operation of pneumatic actuators and services and control of fuel and oxidant tank pressurization from high-pressure bottle supply. The valve has been type tested and is now in production as the basic MD30 type, and also in a number of variations. **Hymatic Engineering Co. Ltd., Redditch, Worcestershire.**

BCE 175 for further information

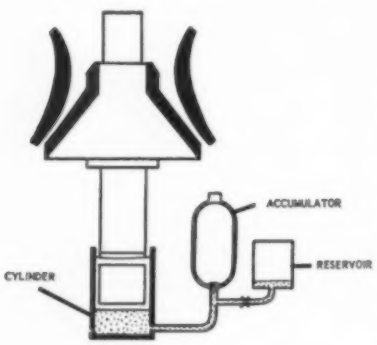
Flexible Furnace

This electrical resistance flexible surface heater is capable of producing transferred heat of controllable temperatures up to 1000°C (1832°F). Temperatures up to 1500°C (2732°F) can be achieved under inert atmosphere conditions. Ceramic blocks and beads are interlocked about the element wires to form a flexible mat of great mechanical strength.



This off-the-shelf heating equipment is available as standard modular units which can be easily linked together and as custom-built units. **Electrothermal Engineering Ltd., 270 Neville Road, London, E.7.**

BCE 176 for further information



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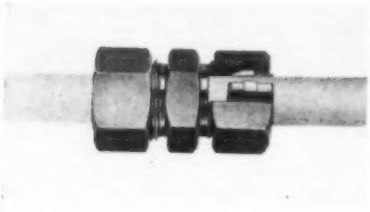
PLANT EQUIPMENT NEWS

Simplifix Couplings for Nylon Tube



The Simplifix nylon tube coupling utilizes a standard Simplifix coupling body, but uses a specially designed olive and nut which prevents the tube twisting when the joint is made. No preparation is required on the end of the tube and the joint can be made using only two spanners. **Alenco Ltd., Beacon Works, Hargrave Road, Maidenhead, Berkshire.**

BCE 177 for further information

New Compact Glass Pump

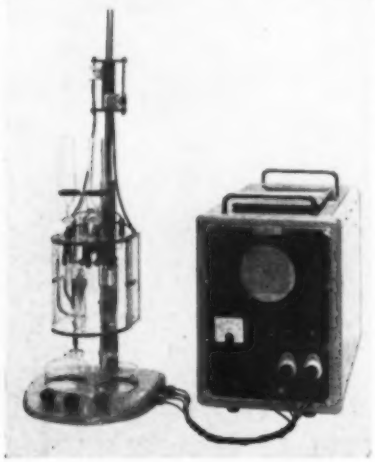
QVF Ltd. have developed a new, compact, centrifugal glass pump, Model GPB, in chemical- and shock-resistant borosilicate glass for pumping corrosive liquids. The pump requires priming. Its glass impeller has six tubular arms which thrust liquid through the tangential outlet in the glass casing, and the motor cannot be overloaded under any operating conditions.

The GPB/6 Model has a 1-hp motor and the GPB/9 Model a 3-hp motor. Both are for a 440 volt, 3 hp, 50 cycles electricity supply. **QVF Ltd., Duke Street, Fenton, Stoke-on-Trent.**

BCE 178 for further information

Differential Cathode Ray Polarograph

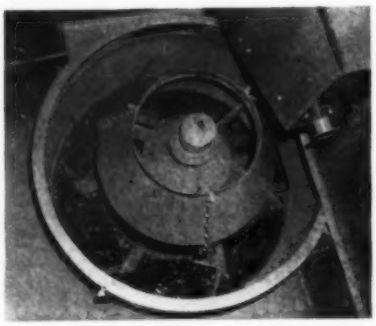
Ability to identify metallic impurities at concentrations down to 0.02 p.p.m. is the major point about a Nash & Thompson instrument. It can be used for soil analysis, for studying the oxygen content of blood plasma or for investigating respiration and photosynthesis in living cells. Numerous inorganic and some organic analyses can also be carried out with greater accuracy than was possible with other types of instrument. **Nash & Thompson, Tolworth, Surrey.**



BCE 179 for further information

Dense Medium Coal Washer Separator

The Norwalt dense medium separating process was first used in a coal washery in Natal, South Africa. While specifically designed for coal, the equipment can be used in any process where solids are to be separated according to their differing specific gravities in a dense medium suspension.



Dense medium separators are of two types, deep or shallow vessels. The company, Nortons-Tividale Ltd., claims that the Norwalt process combines all the advantages of both types.

The capacity of the Norwalt separator ranges from 50 to several hundred tons/hr of raw coal, the only variant being the diameter of the vessel, while the depth is 3 ft in all units. Coal down to $\frac{1}{4}$ in. size can be efficiently separated.

The process was exhibited at the American Coal Show at Cleveland, Ohio. **Nortons-Tividale Ltd., Abford House, Wilton Road, London, S.W.1.**

BCE 180 for further information

Automatic Measurement of Moisture

A new type of moisture meter has recently been developed which automatically effects and records measurements in a matter of minutes on paper discs graduated in humidity percentages. Each material requires a corresponding disc and the values recorded are claimed to be within ±0.3 per cent. A knob at the side of the apparatus governs all operations and the material to be tested is poured into the holder at the top.

The instrument is based on change in dielectric constant. **Compagnie des Compteurs, 12 place des Etats-Unis, Montrouge, Seine, France.**

BCE 181 for further information

Fibre-reinforced Resin Materials

British Insulated Callender's Cables Ltd. will act as distributors to the electrical industry in Great Britain and Northern Ireland of fibre-reinforced resin materials manufactured by Thermotank Plastic Engineering Ltd.

These reinforced plastic materials combine high insulation performance with great tensile strength and are produced by a continuous process of extrusion or of combined extrusion and lamination, in the form of tubes and solid sections in various sizes and profiles in fibre-reinforced synthetic resins. These are already proving valuable in solving problems where high electrical and mechanical stresses occur. Among the applications in which the material offers substantial advantages are stay-wire insulators, operating rods and bars for switchgear.

Metal terminal fittings which enable the great tensile strength of the material to be exploited have been developed and patented. **BICC, 21 Bloomsbury Street, London, W.C.1.**

BCE 182 for further information

Transistorized Photo-electric Detector

Compactness and accuracy at low cost are characteristics of a new transistorized detector unit; performance can be gauged from its ability to detect objects 0.01 in. wide at 4 ft, 0.02 in. wide at 10 ft and 0.025 in. wide at 20 ft.

The standard control unit (designated the CF 69A) complete with two heads costs £14 13s. 3d. less 15 per cent. **Cableform Ltd., Romiley, Cheshire.**

BCE 183 for further information

"Sinex" Minor Constant-weight Feeder

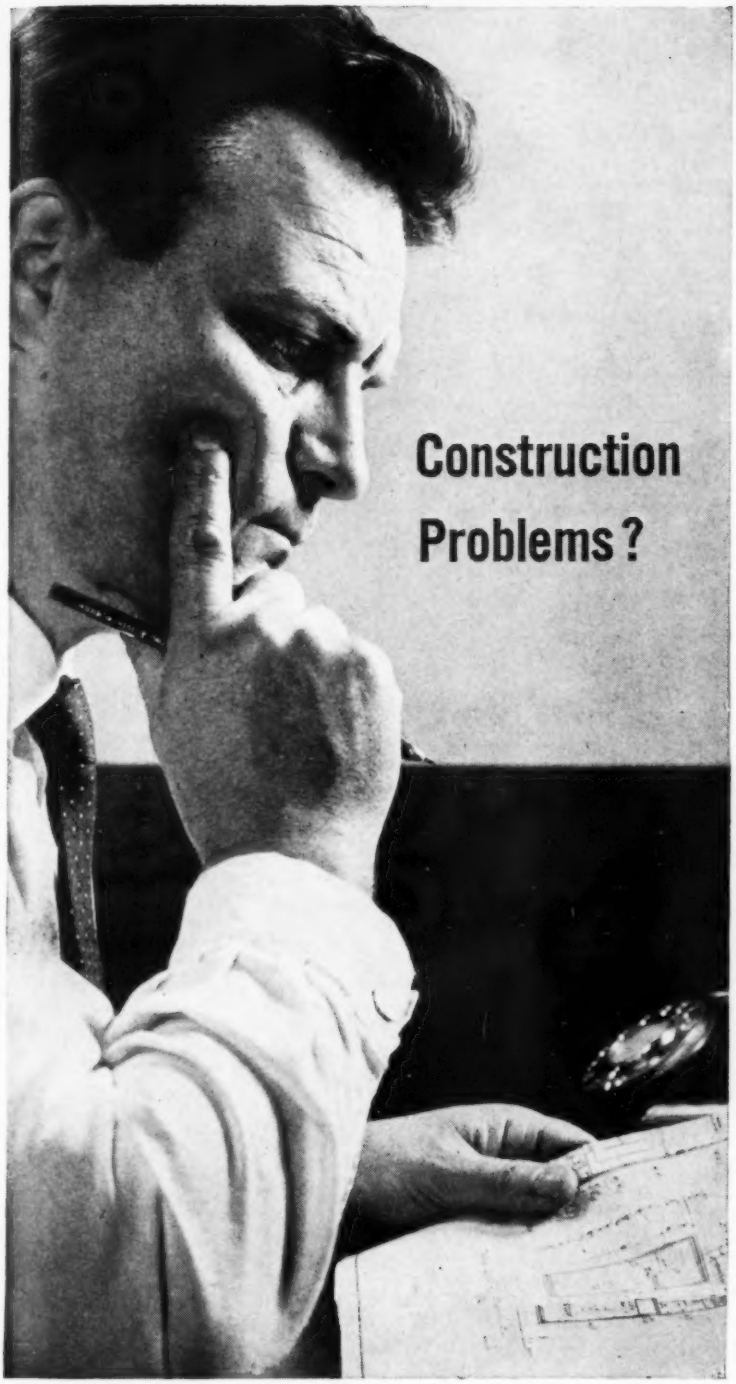
This feeder will weigh accurately any dry powder or granular material at an output rate between 2 and 15 kg/hr with

an accuracy of ±1 per cent. The device, known as the C.W.F., consists of a small buffer hopper, vibratory feeder, weighed belt assembly incorporating a high-speed balance, all housed in a cabinet 2 ft 8 in. cube. The design can allow for electrical interlocking with existing units and remote starting. **Sinex Engineering Co. Ltd., Central Way, North Feltham Trading Estate, Feltham, Middlesex.**

BCE 184 for further information

Differential Refractometer for Process Control

This differential refractometer, known as the Refractosyn, provides a polarized electrical output indicative of the difference in refractive index of two fluids contained in separate cavities of the instrument. Either fluid may, or may not, be flowing.



William Press and Son Limited are carrying out major contracts in Civil Engineering, Pipeline Construction, Industrial Pipework Fabrication and Plant Erection. Its subsidiaries offer a wide range of ancillary services, including the cleaning and reconditioning of every type of pipeline; the manufacture of specialised equipment for the maintenance of pipelines; cathodic protection; welding inspection; central heating; ventilating; steam and hot water services for industrial and domestic purposes.

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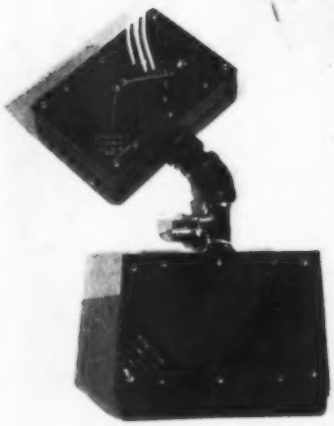
PLANT EQUIPMENT NEWS

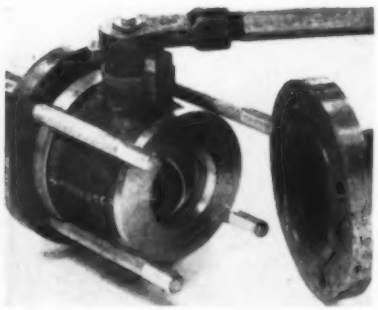


Process control is accomplished by applying the electrical output of the Refractosyn to the control of the process heat-input, mixing ratio, flow rate, turn-off time, etc.

The unit may be used to control a variety of processes in distillation, polymerization, hydrogenation, brewing, etc. It costs less than $1000. **H. H. Controls Co., 7 Leroy Drive, Burlington, Mass., U.S.A.**

BCE 185 for further information

Flanged Ball Valves



A ball valve which can be inserted between two standard flanges and bolted together is now available in 3-, 4- and 6-in. sizes. Numerous combinations of seats, O-rings and body materials make this valve suitable for almost any medium within the pressure-temperature limitations of the sealing materials.

Features include: great port diameter, easy to handle, compactness, easy to maintain. **The Worcester Valve Co. Ltd., 62 Church Road, Burgess Hill, Sussex.**

BCE 186 for further information

Internal Coating of Pipes

A number of recently developed catalysed coatings are suitable for full immersion in chemical plant and their usefulness is now being employed for the lining of pipes.

The following range of coatings is available:

(1) *Epoxides:* (a) solventless epoxy; (b) coal tar-epoxy (two types); (c) phenolic-epoxy; (d) high-build epoxides, both amine and polyamide reacted.

(2) *Polyurethane coatings.*

(3) *Elastomers:* (a) neoprene; (b) hypalon/epoxy; (c) hypalon/phenolic; (d) Viton.

These coatings are produced by E. & F. Richardson Ltd. As a general guide to the most suitable coating for varying service conditions, it should be borne in mind that the elastomers, with the possible exception of Viton, have good all-round resistance to aqueous solutions of most chemicals, both alkaline and acid, together with excellent abrasion resistance at temperatures of up to 110°C. The solventless epoxy materials, on the other hand, have marginally less good abrasion

resistance, but are able to cope with mixtures of solvents and acids or alkalis and do not have the water sensitivity of epoxide-based paints.

The role of polyurethane coatings appears to lie mainly in the potable water field, though solventless epoxide coatings are equally satisfactory. Coating Contractors Ltd. are able to undertake the internal lining of straight metal pipes from 3 in. bore upwards in maximum joint lengths of 40 ft. Within this category, lining thickness, continuity and bond can be checked accurately. Smaller bore pipes in maximum lengths not exceeding 10 ft can be coated; however, inspection is less satisfactory. Curved pipes in all sizes can also be lined. In this class the limitations are mainly economic ones.

The jointing of internally coated pipes presents a problem that has not been entirely solved. In pipes smaller than 21 in. bore, butt welding is at present precluded due to the difficulty of preparing the surface and making good the coating at internal weld margins. In this group, therefore, flanging, screwed fittings or patent pipe couplings are indicated. Sleeve welding, however, is a practical proposition with most of the hard coatings. An automatic shot blasting and hot spraying train which can be employed for the coating of large-bore pipes on site from 60 in. bore upwards has been developed. Speeds in the order of 270 sq ft per hour can be obtained from this equipment, which is at present being used in the penstocks and tunnel linings at the pumped storage scheme at Ffestiniog. **Coating Contractors Ltd., Castle Mills, Buckingham.**

BCE 187 for further information

Economizer for Small Boilers

A well-established economizer is now available for small boiler plants of evaporative capacities in the range 200-12,000 lb/hr. It is a compact, self-contained, shop-assembled unit, completely cased and insulated with dampers and duct connections, and can be installed either indoors or outdoors; gas flow can be upward or downward without modification.

The equipment has diamond-shaped tube body and rectangular fins which give high rates of heat transfer with low draught loss.

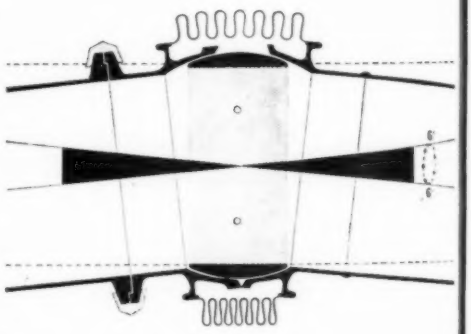
Four sizes are made with 12, 16, 18 and 24 tubes, designed to suit most boilers with pressures up to 650 psi. The fuel savings effected by these units (known as the Unicon) range from 5-17 per cent, depending on the boiler characteristics and operating conditions. **E. Green & Son Ltd., Wakefield, England.**

BCE 188 for further information

Gimbal-type Flexible Joints

These lightweight, flexible joints are designed for insertion at strategic points in ducting systems to relieve, control and contain stresses.

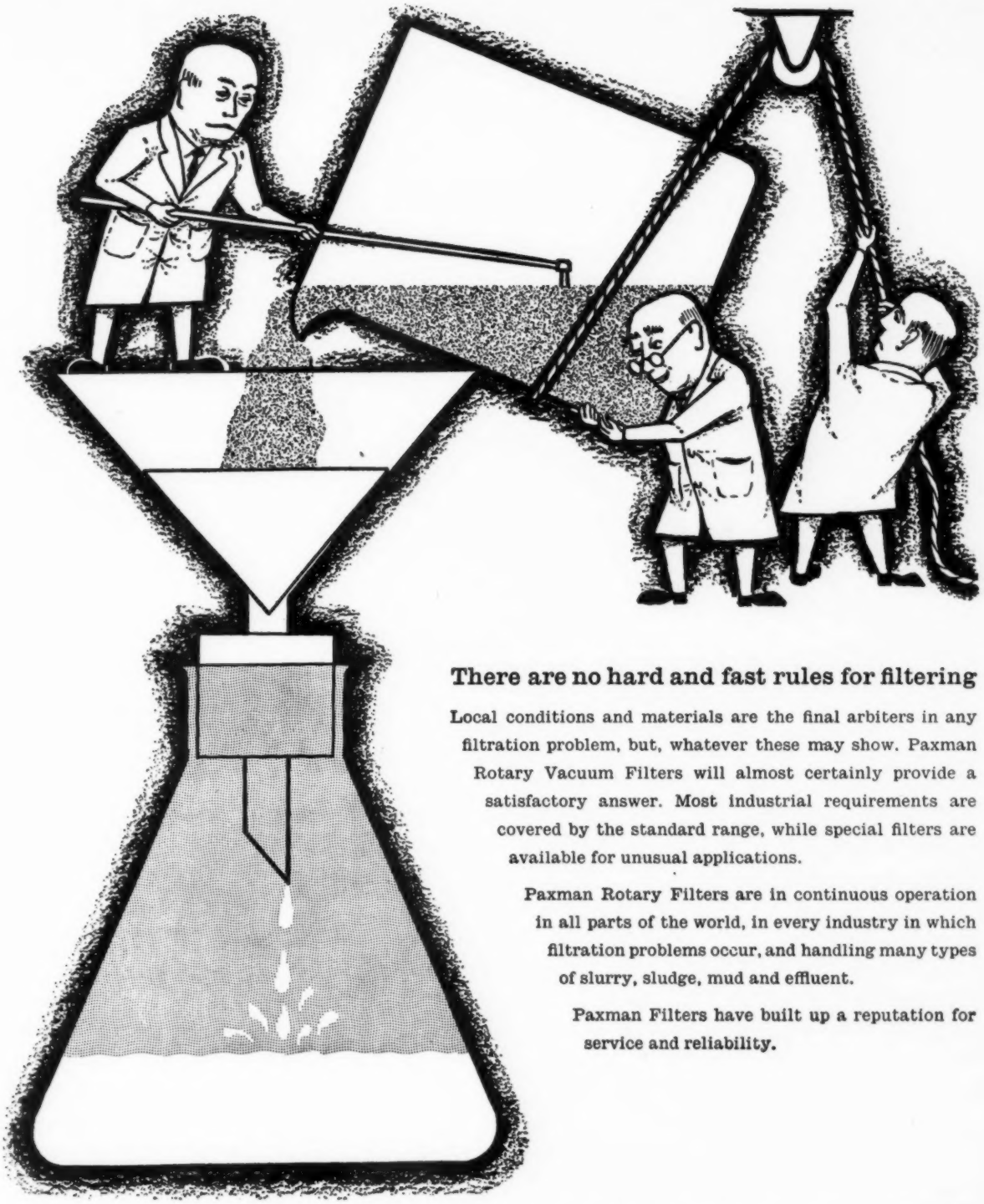
The primary structure, giving stability to the flexible joint and taking all mechanical stresses, is a smooth-bore Gimbal-



type structure allowing an angular displacement of 5-7° from the centre line in any direction. To this primary structure are attached the couplings, flanges, etc.

The secondary structure is a corrugated bellows seal which envelops the Gimbal unit and contains the hoop stresses of the internal system pressure while maintaining a leak-proof seal. The bellows seal is free of mechanical stresses. **Avica Equipment Ltd., Mark Road, Hemel Hempstead, Herts.**

BCE 189 for further information



There are no hard and fast rules for filtering

Local conditions and materials are the final arbiters in any filtration problem, but, whatever these may show. Paxman Rotary Vacuum Filters will almost certainly provide a satisfactory answer. Most industrial requirements are covered by the standard range, while special filters are available for unusual applications.

Paxman Rotary Filters are in continuous operation in all parts of the world, in every industry in which filtration problems occur, and handling many types of slurry, sludge, mud and effluent.

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PLANT EQUIPMENT NEWS

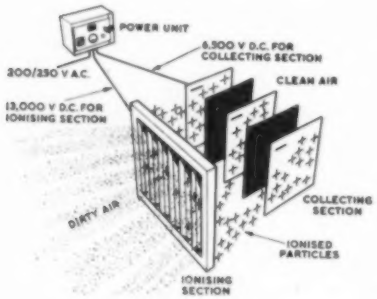
X-ray Fluorescent Spectrometer

The Solartron X-ray fluorescent automatic vacuum spectrometer detects and determines all elements of atomic number greater than 12, though there are certain difficulties with elements between 12 and 20. The X-ray method is particularly valuable for concentration ranges from 0.1 to 100 per cent. Optical spectrometers deal best with trace amounts from 0.0005 to 5 per cent and therefore the two techniques are complimentary rather than alternative. There are some problems, such as the determination of tantalum, niobium or rare earth mixtures, which can only be solved by the X-ray method because of line interference in the optical region. The cost is around £20,000 and the instrument is sold adjusted and calibrated for the customer's own problem. **Solartron Electronic Group Ltd., Victoria Road, Farnborough, Hants.**

BCE 190 for further information

Electrical Air Filter

The removal of all particulate matter ranging in size from 60 microns to 0.001 microns from air and gas streams can be achieved with this filter. As the positively charged particles in the air pass through a



high-voltage ionizing section, they are attracted and adhere to the collecting plates, which form the negative elements of an electrostatic field. Periodically, the accumulation of dirt must be removed. The filter can be used for all forms of air filtration and can be installed in conjunction with other air handling plant. Capacities of units already supplied in the U.K. range from 250 to 200,000 cfm. **W. C. Holmes & Co. Ltd., Gas Cleaning Division, Turnbridge, Huddersfield.**

BCE 191 for further information

New Publications

Impalco Aluminium. A new 67-page brochure presenting technical data on the range of Impalco aluminium and alloys is now available from **Imperial Aluminium Co. Ltd., P.O. Box 216, Witton, Birmingham, 6.**

BCE 192 for further information

Controls for Industry. An attractive, illustrated, 42-page publication describes automatic control equipment of the following types:

(1) Automatic register control for newspaper colour printing.
(2) Control and monitoring equipment for high-speed tyre testing rig.
(3) Drive and automatic control installation for a tyre fabric impregnating and calendering line.
(4) Conveyor control and smoke alarm using photo cells.
(5) Capacitance-operated level control with transistors.
(6) Cut to length control for strips using photo cells.
(7) Finger-tip steering for large machine tools.
(8) Feed control for grinders and pulverizers.
(9) Current control for welding.
(10) Fluid proportioning.

Lancashire Dynamo Electronic Products Ltd., Rugeley, Staffs.

BCE 193 for further information

Dowty Switches. A number of leaflets, available singly or bound in a catalogue, describe the various switches manufactured by the Dowty Group. These include magnetic indicators, limit switches, control systems and solenoids. **Dowty Nucleonics Ltd., Brockhampton Park, Andoversford, Gloucestershire.**

BCE 194 for further information

Measurement Brochure. "Liquid Metering and Dispensing" is the title of a 16-page illustrated brochure now available from Parkinson Cowan Measurement, Tameside Works, Dobcross, Oldham, Lancashire.

The first of a series of three, this new brochure outlines the construction and application of Parkinson Cowan measurement meters for both water and industrial liquids. There is also a valuable section describing some of the many indicating and control devices which can be used with the meters. **Parkinson Cowan Ltd., Terminal House, Grosvenor Gardens, London, S.W.1.**

BCE 195 for further information

Electrostatic Precipitation Plant. The brochure describes a process which removes up to 99 per cent or more of a solid or liquid material suspended in a gas. It handles gases at high temperatures under pressure or suction and the equipment may be built with corrosion-resistant materials. It requires no expert attendance, has no expensive replacement parts, the pressure drop averages a fraction of an inch of water, current and power requirements are low and works in the wet or dry.

This precipitator is produced in two versions. The tube type is used mostly for the removal of liquid or sludge particles and volatilized fumes and the plate type is used primarily for the removal of dry dusts. **Head Wrightson Iron & Steel Works, Engineering Ltd., Teesdale Iron Works, Stockton-on-Tees, Co. Durham.**

BCE 196 for further information

New Brochure on Ammonia Process. This 12-page brochure describes the production of ammonia via steam reforming of natural or refinery gas, and presents the direct operating costs and utility unit costs for ammonia produced by the Kellogg Process, in five major geographical sections of the U.S.A.

The brochure includes process descriptions and flowsheets for the basic process, for one-stage and two-stage reforming operations. An empirical formula, developed by Kellogg, which enables the calculation of feedstock quantity required for any given rate of ammonia production is presented. Kellogg's improved synthesis converter is also described. **Kellogg International Corporation, Kellogg House, 7 Chandos Street, London, W.1.**

BCE 197 for further information

Hygrotherm. A 22-page illustrated publication describes the activity of Hygrotherm Engineering Ltd., who provide consulting and contracting services through their Chemical Plant Division, Heat Transfer Division and Research Division.

The Chemical Plant Division designs, supplies, erects and commissions complete chemical plant for the manufacture of various resins, distillation units and multiple-effect evaporators, particularly those requiring special materials of construction.

The Heat Transfer Division supplies complete heating systems using high-temperature water, steam, diphenyl/diphenyl oxide, hydrocarbon oils and tetra aryl silicates. Waste heat recovery plants and a variety of other equipment are also developed.

The Research Division advises clients on the choice of heat transfer media for particular applications. A technical service is provided for users of the Hygrotherm TAS liquids and of other heat-transfer media. **Hygrotherm Engineering Ltd., 5 Fitzhardinge Street, London, W.1.**

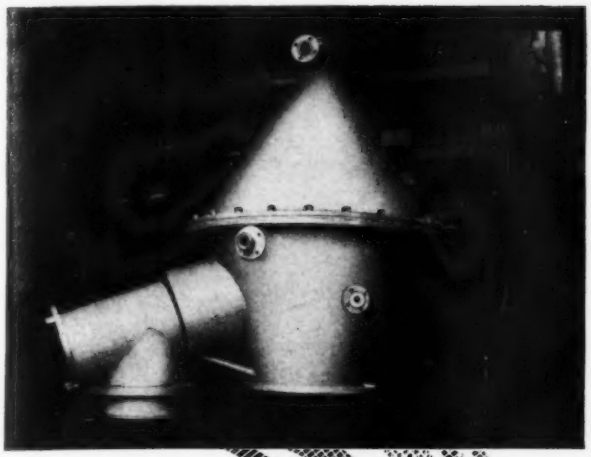
BCE 198 for further information

Turners' Asbestos Textiles. This illustrated 32-page brochure describes the range of asbestos products available and gives details of the variety of applications which asbestos textiles find in the electrical field. **Turner Brothers Asbestos Co. Ltd., Rochdale, U.K.**

BCE 199 for further information

Anti-corrosive and Protective Materials. This 7-page brochure lists some 300 anti-corrosive and other protective materials manufactured to government and other official specifications. **Croda Ltd., Cowick Hall, Snaith, Goole, Yorkshire.**

BCE 200 for further information



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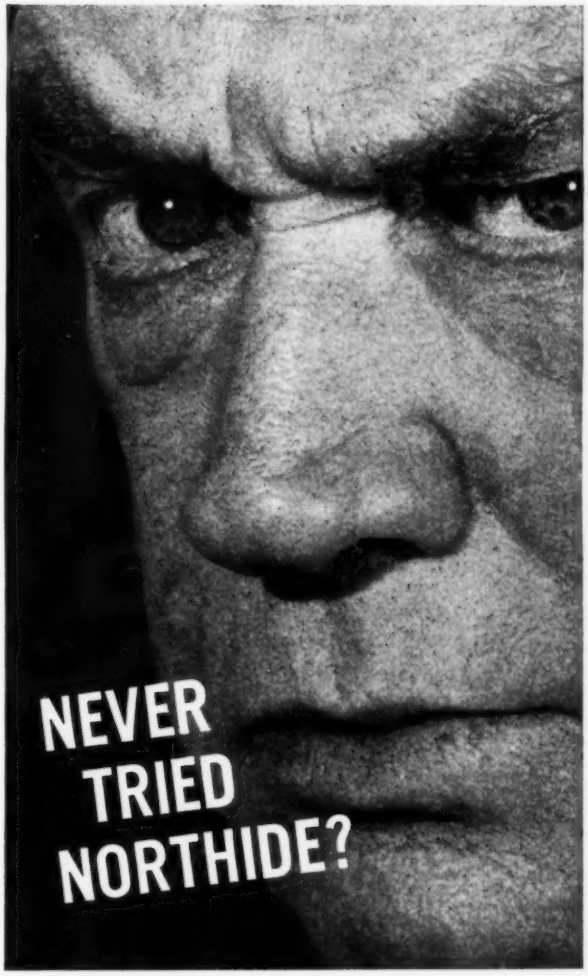

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World of Chemical Engineering

New Plants

More Nitrogen

A new plant which will increase the production capacity of nitrogen supplies to the Wilton works of I.C.I. by 50 per cent is to be built by the **British Oxygen Co.** It will cost £½ million and will produce 5000 cu m/hr of very high purity nitrogen for use in the manufacture of terylene, nylon, titanium, propathene, and in other cracking processes.

From India comes news that her second nitrogenous fertilizer plant, at Nangal, produces 200 tons of calcium ammonium nitrate per day and will eventually produce 800 tons of fertilizer a day. Agricultural chemicals, this time plant protection products, are to be manufactured by **I.C.I.** in Nigeria at a new plant to be constructed near Lagos. They will be used to help the cocoa-growing industry. A paint factory will also be established on the same site.

A new mercury-type cell installation to produce chlorine and caustic potash will be opened by August 1 at the Niagara Falls plant of **Moffit & Bryant**. It is the first phase of a four-step electrolytic cell expansion project.

Oil Refineries

The first oil refinery to be built in Singapore is being opened on July 26 by the Singapore Finance Minister. It is the **Shell refinery** built on the island of Palau Bukom, and will be capable of processing a million tons of crude oil a year. It will meet all local demands for petrol, aviation turbine fuel, kerosine, gas oil, diesel fuel and fuel oil.

The possibility of building another new refinery, this time in South Africa, is being examined by **Caltex (Africa) Ltd.** If constructed, it is expected to cost £12 million, will be in the Cape Town area, and will have off-shore discharge facilities.

News of expansion comes from the Dunkirk refinery of BP's French associate, **Société Française des Pétroles BP.** The annual capacity has been raised from 2.3 million tons to 2.9 million tons of mixed Middle East/Sahara crude.

Gulf Oil Corporation are to build their first European refinery, in Denmark. The contract for its construction has been awarded to the **Kellogg International Corporation**, London. Capacity will be 1½ million tpa of crude oil.

Petrochemicals

Mobil Chemica Italiana SpA is to build a petrochemical plant at Naples to utilize the products of the neighbouring Mobil refinery. The initial capacity of 150,000 tpa will consist of 75 per cent benzene and orthoxylene and 25 per cent ethylbenzene and paraxylene. Another petrochemicals project is announced by the **British American Oil Co. Ltd.**, who have started operations of a 7000 barrels per stream day Udex unit at their Montreal refinery.

An Institute of Petroleum Research is to be built in Cairo, U.A.R., by the Federal German Republic. From Greece there is news of a new plant to process liquefied petroleum gases produced at the refinery at Aspropyrgos, south of Athens. Annual production will be 50,000 tons.

Another interesting project just completed is a 6-in. pipeline 29 km long for transporting natural gas from the Rosh Zohar deposits in Israel to the Dead Sea potash works at Sodom. Eventual capacity will be 100,000 tpa after the first three years.

Courtaulds Ltd. announce in their annual report that work on petrochemicals has been accelerated, and a semi-commercial plant has been erected at Spondon to make peracetic acid and various epoxy derivatives.

Organic Chemicals

The Du Pont Co. (U.K.) Ltd. announce plans to manufacture isocyanates, a basic raw material used in urethane foams, at a new multi-million-pound plant to be built on their Maydown site in Northern Ireland.

Another firm, **Cyanamid of Great Britain Ltd.**, have started producing melamine crystals at the rate of 3000 tpa at their Gosport, Hants, works. It is used in the manufacture of laminates and moulding powders.

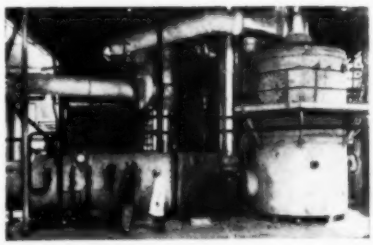
Grange Chemicals Ltd. are to make 15,000 tpa of phthalic anhydride at a new plant to be built adjacent to the Salt End Chemical Works of the Distillers Co. Ltd. in Hull.

The first South African factory to produce **citric acid** is to be built on the Natal North Coast at a cost of R 1 million. Sugar-cane molasses will be processed by a new method.

Textiles and Plastics

Courtaulds Ltd. and **I.C.I. Ltd.** have both announced plans for the production of caprolactam, upon which nylon 6 is based. It has extensive outlets in the manufacture of textiles, fibres and plastics. The Courtaulds process, based upon toluene, is the most economic one so far discovered, and was acquired from their associated company, **Snia Viscosa of Milan**, Italy. The new plant will produce 10,000 tpa of caprolactam. I.C.I. have concluded an agreement with **Emser Werke AG/Iventia AG** of Switzerland to use their process, and will construct a plant to produce 15,000 tpa on their Severnside site. A plant for the large-scale production of nylon 6 polymer will be built concurrently.

Other plans announced by **Courtaulds Ltd.** are for the construction of a number of plants including a unit to produce pure benzene, toluene and a xylene fraction from an aromatic by-product.



The new Contact process sulphuric acid plant recently commissioned at Stratford by F. W. Berk & Co. Ltd. incorporates a modern fire tube boiler and a four-pass converter.

Fabrication Facilities

The Scottish equipment firm of **Dickson & Mann Ltd.** have just completed expansions and diversifications lasting two years. A 15,000 sq ft extension was opened at their Bathville Steelworks on June 30. The firm is one of Britain's leading manufacturers of coal-handling and bulk-handling equipment. Another firm who have plans to build a new heavy fabrication shop are **Henry Balfour & Co. Ltd.** The shop, 300 ft by 80 ft, will be built on a 25-acre site adjacent to their Research and Development Centre at Mountfleurie, Fife.

Irradiated Fuel Processing

The Eurochemic Co. has agreed on the main specifications for its new plant for the chemical reprocessing of irradiated fuel at Mol in Belgium. Construction will now begin in collaboration with the French Company **Saint-Gobain Nucléaire.**

In order to gain the maximum experience, the plant has been designed to accept a wide range of fuel types. The specification allows for a capacity of 350 kg/day for natural uranium elements or 200-250 kg/day for enrichments up to about 5 per cent.

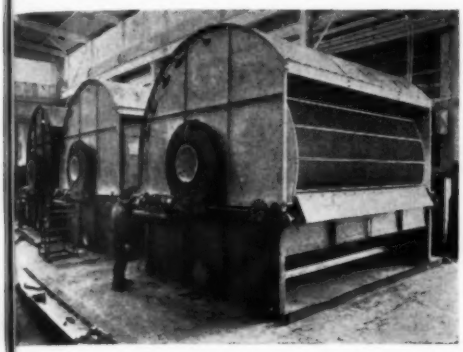
75th Anniversary

The British Oxygen Co. Ltd. celebrates its 75th anniversary this year. To mark the occasion they have made a film called *O for Oxygen*. It shows the world-wide use of oxygen and other industrial gases in industry, medicine, aviation and scientific development. Copies of the film in 16 mm and 35 mm, will shortly be available for free loan from the company.

Contracts

Exports to Poland and U.S.S.R.

Among recently announced contracts is one for the supply of a 500-tpd urea plant to Poland. The urea is to be used for fertilizers. The contract has been secured by **The Power-Gas Corporation Ltd.**, who will use a process licensed from **Toyo Koatsu** of Japan. Another export order, to supply a £140,000 filtration plant to the U.S.S.R., is being completed by **Eimco (G.B.) Ltd.** It is part of a £7½ million contract to construct two beet sugar factories in the Ukraine awarded to **Vickers & Bookers Ltd.**



These rotary vacuum filters are part of the £140,000 export order for filtration equipment for two sugar beet factories in the Ukraine, mentioned on this page.

Greece's third sugar refinery, which will have a capacity of 2000 tpd, is being built by the Italian firm **Nuove Reggiane**.

Oil Strike in Italy

Oil has been discovered at a depth of 2020 metres near Pisticci, Italy, by **A.G.I.P. Mineraria**, the prospecting company of **E.N.I.** Another E.N.I. project is the construction of a pipeline to transport petroleum from Genoa to Munich across the Alps.

Also from Italy comes news that the American **Foot Mineral Co.** is negotiating for the installation of an electrolytic plant to produce manganese at Carbonia. In the petrochemical field, a plant costing over £1 million and producing 15,000 tpa of carbon black has been built and commissioned by **Techint** of Milan for **Cabot Engineering Co.**, at Ravenna. It thermally dissociates aromatic oils in special high-temperature furnaces.

British Plant for Italy

Lightnin Mixers Ltd. have secured two orders for their fluid mixing equipment. They are being used at the antibiotics plant of **Fervet SpA** in Milan and by the **Compagnia Tecnica Industrie Petroli**. A plant for the production of butadiene-styrene resin and latex will be built by **W. R. Grace & Co.**

In England, **Lodge-Cottrell** will be supplying Dorman Long with a further five precipitators for Lackenby Steel Plant oxygen-blown open-hearth furnaces. **Laporte Industries Ltd.** will build a £4 million titanium oxide plant at Bunbury, Western Australia, with an annual capacity of over 10,000 tons.

Company News

G.E.C. forms Marketing Company

Important announcements in this field during the month include the formation of two new companies and the acquisition of a controlling share interest by two others. **International Systems Control Ltd.** has been formed to market industrial process control systems in Great Britain, the Commonwealth and the European Free Trade Area. It was formed by G.E.C. Ltd. (England) and Thompson Ramo Wooldridge Inc. (Los Angeles).

A new Italo-Tunisian petroleum company, **S.I.T.E.P.**, has been formed to prospect for oil in the South of Tunisia between Gabes and the Libian frontier.

The companies taking over share control are **Castrol Ltd.**, who are to acquire 75 per cent of the share capital of Melwood Thermoplastics Ltd. of Harpenden and the entire share capital of Tensile Products Ltd., and the **Dow Chemical Co.** of the U.S.A. They are obtaining all the shares of their British subsidiary, Dow Agrochemicals Ltd.

International Co-operation

There is also news of co-operation and exchange of "know-how" between firms in different countries. **Courtaulds Ltd.**, who have recently acquired a small interest in the **Koppers Co. Inc.** of U.S.A., have completed preliminary plans for the exchange of technical, process and production "know-how" in matters of mutual interest outside the field of textiles. Also, the **Albright & Wilson Group** are co-operating with **Villa Aufricht & Cia** of Argentina in connection with the construction of a plant for the manufacture of phosphoric acid from phosphorus at Buenos Aires. Engineering services, special equipment and technical information will be provided by the British company.

Personalities

Mr. H. W. Jones is the new Technical Manager of Process Plant Contractors (Campbell) Ltd.

Mr. W. G. B. Mills has been appointed Deputy Manager of BTR Industries Ltd.'s Thermo Plastics Research and Development Laboratory at Silvertown, London.

Mr. H. W. Vallender is the new Deputy Director of the Association of British Chemical Manufacturers.

Mr. E. Jarman has joined the Council of British Manufacturers of Petroleum Equipment as Technical Adviser, having relinquished the post of Head of the Mechanical Engineering Division of the Kuwait Oil Co.

Mr. G. McClune has accepted an invitation to join the Board of Nordac Ltd, Chemical Engineers, of Uxbridge.

The National Coal Board have appointed Mr. C. W. Moss as Assistant Director General of the process Development Dept.

Dow's European Activities

Two years ago, Dow Chemical International Ltd. S.A. was reorganized from an export company to an international marketing organization. Sales offices were established in London, Frankfurt, Brussels, Milan and Zürich, primarily to develop markets for products which Dow will be manufacturing in Europe.

Nederlandsche Dow Maatschappij N.V., a subsidiary of the international company, have now built a plant in Rotterdam to produce various types of styrene-butadiene latexes. Dow's Rotterdam facilities include a shipping terminal, bulk storage capacity and a Coatings Technical Service Department staffed with experienced personnel and equipped with an up-to-date laboratory. This department will provide the necessary technical service and assistance required by Dow's European customers.

An interesting safety feature of the plant is a cylindrical chute which provides rapid escape and safe landing in emergencies.

In addition to the styrene-butadiene latex plant in Rotterdam, polystyrene production plants are under construction in Lavrion, Greece, and in Livorno, Italy.

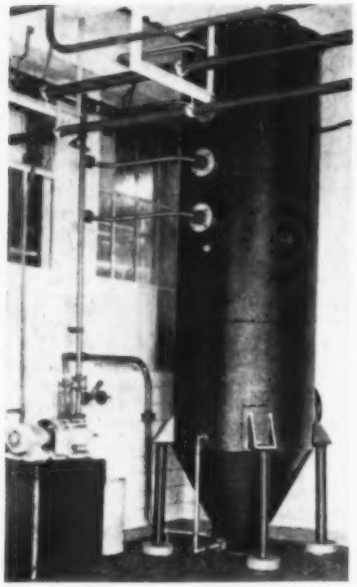
Some Problems Solved

Metallic Materials of Construction for Temperature Extremes

The behaviour of materials at temperatures well below zero has become an important matter in recent years, mainly because many branches of industry are now faced with the need to handle and store liquefied gases. A case in point is the tonnage oxygen plants, and the various facilities required for handling and distributing methane. The problem of selecting a suitable material of construction, both for storage vessels and processing equipment operating at the low temperatures in the region of −190°C, may well be met satisfactorily by the use of 9 per cent nickel steel. Recent large-scale tests conducted in the U.S.A. have shown that the material is highly suitable and the cost of pressure vessels made from the alloy may be as much as 15 per cent cheaper than those fabricated from the most competitive alternative material.

Where high-temperature service is involved a number of problems may arise; for example, in the tuyeres of blast furnaces, where the temperatures may be in the range 700-800°C. The particular components to suffer are the pipes supplying blast air to the tuyere nozzles around the furnace. According to tests carried out by the Appleby Frodingham Steel Co. at their Scunthorpe works, the most suitable material is a 22.5 per cent chromium 11 per cent nickel from which the pipes are centrifugally cast. Whereas the original steel pipes lasted merely a month, pipes of this material have given over a year's service, despite the high blast temperatures.

Plastics for Corrosion Resistance



The use of plastics as materials of construction has been illustrated by a number of installations dealing with situations of varying severity. One such case has been reported at Courtauld's "Fibro" manufacturing plant, where the particular problem was to provide piping capable of carrying air saturated with water vapour and containing both CS_2 and H_2S. A very convenient solution to this problem was the use of PVC dipped ducting which was especially suitable in view of the ease with which the protective coating can be applied to intricate bends and awkward shapes. The dipping for this pipework was undertaken by Plastics Coatings Ltd., Guildford, using a paste based on Geon 121 PVC resin.

PVC has been much to the fore for applications where complete freedom from product contamination as well as from corrosion is required. Such an example has been reported where copper pipe has been replaced entirely by high-impact PVC pipework.

PVC has figured in a number of other applications, one example being at a plant producing dry sodium chlorite. Here one of the final stages in the manufacturing process is the drying of the powder in a stream of warm air. At this plant the problem was the corrosion which occurred at the last stage of the process where the air discharged to atmosphere tends to carry with it a certain amount of dry sodium chlorite. The tower employed for treating this air has liquid sprays in order to dissolve any entrained residue. It operates at 80°C and the rubber-lined steel unit originally employed failed after a fairly short life. Stainless steel was also tried, but this, too, failed rapidly. The solution finally adopted was a scrubbing tower constructed of bonded laminated unplasticised PVC, the reinforcing medium being a fibreglass epoxy resin. The supplier was Tough Plastics Ltd., and not the least interesting thing about the equipment is the fact that it has been supplied to a German firm, Elektrochemische Werke München A.G., Munich.

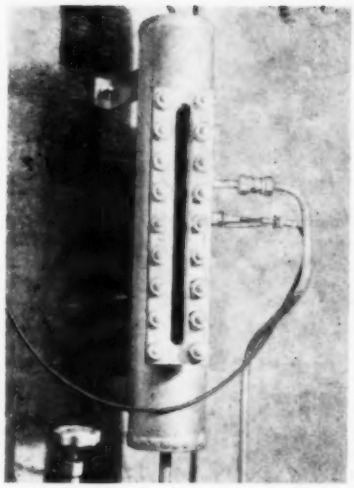
Improved Powder Handling

A considerable improvement in the handling of powdered solids was brought about by the use of a portable auger or screw conveyor. The task was to transfer granulated raw shellac into large vats, which was previously performed by an operator who had to raise 1-cwt. sacks and tip them into the vat mouths. By means of the adapted conveyor, including its attachment to a portable hopper, the plant operator can now unload sacks into the hopper from ground level and allow the conveyor to transport the shellac to the vat. Apart from reducing his manual effort considerably, this gives him time

to attend to process conditions and controls. A further advantage arising from this improvement is the virtual elimination of dust formation. This is achieved by surrounding the delivery chute in the vat with a ring carrying several nozzles. Water is projected through these in fine sprays which arrest the dust issuing from the end of the conveyor. It has been found, for the most effective operation, that the inlet slide of the conveyor be closed to an extent below the design minimum. The adapted equipment (a Mayrath conveyor) described above was supplied by Gordon Felber & Co. Ltd. to A. F. Suter & Co. Ltd.

"Proximitor" Detects Interface between Oil and Water

The necessity for separating gas, oil and water in an oil cracking process* set its own particular problem when it became necessary to detect the interface between oil and water. Due to the tarry nature of the oil, any sight glass became quickly fouled. Conductivity mesurement was tried but proved unsuitable, since the tarry oil coated the probe and interfered with the detection.



It was decided to use a "Proximitor" capacity operated relay.† A sparking plug was modified for use as a probe in conjunction with the unit, with the happy result that, as the aqueous layer reaches the probe, a relay operates, due to differences between the dielectric constants of the aqueous and oil phases, actuating a magnetic valve which controls the water off-take. The aqueous phase often contains small amounts of emulsified oil, but the presence of this has not affected detection of the interface.

In the picture the modified sparking plug "probe" can be seen on the right of the sight glass to which is connected the "Proximitor" capacity operated relay which makes possible detection of the interface between the oil and water.

* Sunbury Research Centre, British Petroleum Co. Ltd.

† Manufactured by the Electronic Machine Co. Ltd., Mayday Road, Thornton Heath, Surrey, from whom full details are available.

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Survey of Digital Computer Applications in the United States—Part II

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Recent Advances in Materials of Construction—Report of a Symposium

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